AGRONOMY SEMINAR
305 DAVENPORT HALL

ОЧВОВЕДЕНИЕ

SOVIET SOIL SCIENCE

2

FEBRUARY 1961

A TRANSLATION
OF POCHVOVEDENIYE

★

AMERICAN INSTITUTE
OF BIOLOGICAL SCIENCES
2000 P STREET, N.W.
WASHINGTON 6, D. C.

SOVIET SOIL SCIENCE

A. P. MAZURAK, *Editor*
Department of Agronomy, University of Nebraska

Patricia Haley
Assistant Editor

American Institute of Biological Sciences

Officers
Tracy M. Sonneborn, *President*
Bernard S. Meyer, *Vice-President*
F. P. Cullinan, *Secretary-Treasurer*

Executive Director
Hiden T. Cox

Chairman,
Committee on Translations
Fred R. Cagle

Director of Publications
Francis C. Harwood

Governing Board
George Beadle
Albert P. Blair
Fred R. Cagle
David E. Davis
E. L. Dulaney
Wallace O. Fenn
Clifford Grobstein
A. M. Guhl
Freeman S. Howlett
Paul J. Kramer
W. Gardner Lynn
Dorothy Matala
George L. McNew
Bernard S. Meyer
Fred S. Orcutt
F. W. Poos
Roger D. Reid
Reed C. Rollins
William Steere
John A. Stevenson
Karl A. Stiles
Carl P. Swanson
Kenneth Thimann
Arthur C. Walton
Richard G. Zweifel

The translation and publication of this and other Russian language biological journals and monographs is a project of the American Institute of Biological Sciences. This project is supported by grants from the National Science Foundation. Each publication is a cover-to-cover translation of its Soviet counterpart and the contents are only those of the original authors.

Pochvovedeniye in English translation bears the Soviet issue numbers. The Soviet journal carries no volume numbers. Translation begins with Number 1, the January 1958 issue. It is published in the same number of issues per year as the original Soviet journals: 12 issues.

translated and produced by
ROYER & ROGER, INC.
INTERNATIONAL DIVISION

Subscription Prices:
$40.00 per year, individuals and industrial libraries
20.00 per year, university and non-profit libraries
3.00 additional to each price for foreign orders
4.50 each, single copies

Order from:

American Institute of Biological Sciences
2000 P Street, N.W., Washington 6, D.C.

© 1961 American Institute of Biological Sciences

SOVIET SOIL SCIENCE

A translation of the monthly journal—POCHVOVEDENIYE—
a publication of the V. V. Dokuchayev Institute of Soil Science,
Academy of Sciences, USSR. A journal founded in 1899.

Pochvovedeniye Editorial Board: I. V. Tyurin (editor-in-chief), I. N. Antipov-Karatayev, N. I. Gorbunov, K. P. Gorshenin, A. A. Zavalishin, V. N. Zavaritskii, S. V. Zonn (assistant editor), O. K. Kedrov-Zikhman, V. M. Klechkovskii, V. A. Kovda, M. M. Kononova (assistant editor), Ya. V. Peive, I. I. Sinyagin, A. V. Sokolov

---

No. 2: February 1961 Translation printed: February 1962

CONTENTS

	Page	Russian Page
TASKS OF SOIL SCIENTISTS IN THE LIGHT OF THE RESOLUTIONS OF THE JANUARY PLENUM OF THE CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE USSR	113	I
ZONAL STUDY OF THE MINERAL FERTILIZER RATES AND LARGE-SCALE SOIL MAPS, by P. G. Naydin and N. N. Mikhaylov	115	1
CERTAIN METHODS OF RATIONALLY UTILIZING SOIL MOISTURE IN TEA PLANTATIONS, by M. K. Daraseliya	122	10
NUTRIENT REGIME OF THICK CHERNOZEMS IN THE FOREST, THE STEPPE, AND IN A PLOWED FIELD IN THE KURSK RESERVATION AREA, by D. M. Kheyfets	129	18
CHARACTERISTICS OF THE AGGREGATION OF SOILS IN THE SOUTHEAST, by A. I. Skrepinskiy	136	26
WATER REGIME OF ORDINARY CHERNOZEMS IN THE KAMENNAYA STEPPE, by I. P. Sukharev	142	33
DYNAMICS OF IRON IN SOLONETZES OF THE TRANS-TISZA REGION OF HUNGARY, by Laslo Gerei	151	44
CELLULOSE DECOMPOSITION IN THE ZONAL SOILS OF TADZHIKISTAN, by A. F. Zakharchenko	160	54
METHODS		
UPWARD MOVEMENT OF SUSPENDED MOISTURE IN SOILS OF THE STEPPE GROUP, by L. G. Balayev	167	63
FREEZING AND THAWING OF SOIL UNDER VARIOUS TREATMENTS IN THE NORTH KAZAKHSTAN OBLAST', by V. Ye. Kazakov and R. S. Aynikeyev	173	69
USE OF THE RADIOACTIVE ISOTOPE P^{32} IN STUDYING PHOSPHORIC ACID MOVEMENT IN THICK CHERNOZEM, by P. P. Levenets	179	74
CHANGE IN HUMUS COMPOSITION IN THE ANNUAL CYCLE OF SOD-PODZOLIC SANDY LOAM SOIL, by A. V. Baranovskaya	183	79

	Page	Russian Page
INFLUENCE OF PROLONGED, SYSTEMATIC APPLICATION OF FERTILIZERS ON HUMUS ACCUMULATION IN SOIL, AND THE AGRICULTURAL CROP YIELDS, by N. G. Gorodniy	190	86
CHEMISTRY OF ORTSTEINS IN SOD-PODZOLIC SOILS, by B. N. Pol'skiy	198	93
USE OF ANIONITES IN DETERMINING THE CONTENT OF AVAILABLE PHOSPHATES IN SOIL, by L. V. Sidorina	201	96
DETERMINATION OF AMMONIUM IN THE SOIL BY THE ACID EXTRACT METHOD, by N. M. Mayboroda	206	100
SOIL INVESTIGATIONS IN NORTHERN ALASKA, by I. S. Mikhaylov	209	103

REVIEW

	Page	Russian Page
SOIL SOLUTIONS OF THE SOUTHERN PART OF THE FOREST ZONE AND THEIR ROLE IN CONTEMPORARY SOIL PROCESSES, by I. N. Skrynnikova	215	109

CHRONICLE

	Page	Russian Page
SOIL SCIENCE AND GEOGRAPHY, by K. P. Gorshenin	220	114
ABRAM FEDOROVICH IOFFE, by Agricultural Physics Institute, Academy of Agricultural Sciences and Editorial Office of Pochvovedeniye	223	117
BIBLIOGRAPHY	224	118

TASKS OF SOIL SCIENTISTS IN THE LIGHT OF THE RESOLUTIONS OF THE JANUARY PLENUM OF THE CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE USSR

The resolutions of the January Plenum of the Central Committee of the Communist Party of the USSR constitute an important event in the life of our country. Noting the fast development of the peoples' economy, including that of agricultural production, the Plenum uncovered shortcomings in the development of agriculture and showed a lag in the growth rate and the level reached in the production of agricultural products, especially in animal husbandry, behind the set 7-year plan.

The Plenum specified that a steady increase of agriculture is one of the most important conditions for building a communistic society.

For the successful development of national economy and the raising of the standard of living of the people, the growth of agricultural production must exceed demand, as stated in the speech of N. S. Khrushchev, and in the resolutions of the Plenum of the Central Committee of the Communist Party of the USSR.

An important task of agriculture, as indicated in the resolutions of the Plenum, is to increase greatly in the near future the production of grain, industrial crops, potatoes and vegetables, meat, milk, and other products.

To achieve these goals, agriculture must be based on scientific principles, and strive toward such a state that the quantity of products be increased under any climatic conditions in the country.

At the present time our country can increase its capital investments (above those specified in the 7-year plan) to develop agriculture and the industry which serves agricultural production. In relation to this the Plenum plans to step up the delivery of agricultural machinery in the near future, as well as the production of mineral fertilizers, herbicides, and toxic chemicals.

To ensure an increase of agriculture it is necessary that agriculture continue to develop and be improved, and that the achievements of science and the experience gained be persistently introduced into the practical work of kolkhozes and sovkhozes. The agricultural Ministry of the USSR must focus a great deal of its attention on the realization of this goal.

Special attention was paid at the Plenum to the problem of the development of irrigation—the irrigating and flooding of millions of hectares of land in the southern regions of the country. Together with irrigation, work must be conducted on the drainage of water-logged and excessively wet lands outside the chernozem belt.

Following the resolutions of the January Plenum of the Central Committee of the Communist Party of the USSR, soil scientists must focus their attention on the more active servicing of agricultural production.

To organize agricultural production properly, a knowledge of the existing soil resources is imperative. This requires a well-planned quantitative and, especially, qualitative assessment of the available soil resources. In this respect, the construction and elaboration of medium and small-scale maps for individual republics and various regions is of great importance. One of the tasks in this field is the assessment of the extent of virgin land under abandonment, overgrown with shrubs, etc., which can be drawn into agricultural production. Agronomical features must be introduced into soil maps, to a greater extent than has been done previously. The maps must give information relating to areas with various soil categories and data on the extent of land that can be reclaimed for various purposes. At the same time, they must reflect the agricultural-chemical properties of various soils, as well as other indices of production, in particular certain of their physical and technological properties. These materials are necessary to establish the need for fertilizers, to plan fuel consumption for tillage, and particularly to increase the speed of implements, etc. Finally, such materials can be used during the construction of machines and can determine the number of special types of implements being manufactured by the industry. A number of indices characterizing the physical properties of soil are also required in planning various types of agricultural melioration. Now, after N. S. Khrushchev has stated the need for soil maps, they must be compiled on a much larger scale. Each kolkhoz and sovkhoz must be provided with soil maps. However, the problem is far from being solved by only the construction of a soil map. In spite of the fact that it is difficult to farm properly without knowing soils, there are still many farms at which soil maps, compiled earlier, are not being used properly. In order to use them properly, the agronomists must be better trained in the problems of soil science; and soil scientists, in turn, must be better trained in agronomy. It is extremely important that a soil map for an individual farm reflect not only the quality of the soil, but also contain in the form of recommendations, special schematic maps and other materials, plus concrete suggestions on the proper use of various soil groups and ways of increasing their fertility. In relation to this, soil science research institutions must accelerate the development of improved methodological instructions on the construction of soil maps for kolkhozes and sovkhozes. They must also finish their work on the classification of arable soils, which should be more closely related to their site quality. When selecting the topographical basis for soil mapping, aerial photographs should be used, if possible. This would increase the quality of soil surveys and accelerate work considerably.

An important problem, which must always be kept in the minds of soil scientists and agronomists, is that of the use of mineral and organic fertilizers. It is not necessary to touch on all the problems relating to this; they can be united under one general concept—the agricultural-chemical servicing of agricultural production. To solve this problem it is necessary first of all to determine the need by various soils of mineral fertilizers, and at the same time to determine their effectiveness in various soils under various crops. Recommendations must be worked out as soon as possible on the more rational utilization of such amounts of fertilizers which actually can be produced by the industry.

Considering the low production of mineral nitrogen fertilizers, attempts should be made to increase the supply of biological nitrogen in soils by sowing legume crops, but not to the detriment of the growth of the planned crop. It is necessary to utilize organic fertilizers more effectively. In all these problems agriculture needs the help of science.

The damage brought to agriculture by soil erosion is well known to all. In areas where there is a deficiency of soil moisture during the growing period, erosion control is simultaneously the control of soil droughts. The combination of measures for the control of soil erosion and soil moisture conservation could substantially increase crop yield in regions with developed erosion. To eradicate erosion, the whole complex of agricultural practices must be considered as soil-protection. Agricultural means must be supplemented by special measures regulating snow melting and the runoff of spring and rain waters, or adapted to the prevention of wind erosion. Being interrelated, these measures must embrace the whole territory of the natural region as a whole, and must not be limited to only one land use. In order to do this it is necessary to work out general state, or interkolkhoz, projects for the corresponding measures, using the most modern achievements of domestic and foreign science. It is especially desirable to enlist a wide circle of people to fulfill such measures.

Soil scientists must also focus their attention on the methods of plowing various soils, and even more on differential methods of soil tillage in various zones and provinces. The problems of deep meliorative plowing of sod-podzolic soils, as well as solonetzes and certain other soils, are of special significance as a means of creating a thick plowed layer having a high fertility.

The Plenum devoted a great deal of attention to problems of the development of irrigation in Central Asia, in southern Ukraine, in the Northern Caucasus, and in other regions of the country. The Party and the Government repeatedly stressed the need for the development of irrigation; the problem now is to double the extent of irrigated land in the near future. Let us recall that it took centuries to build up the existing irrigated land in our country.

The most important problem in organizing new irrigation is the selection of suitable lands, and the soil-meliorative evaluation of the corresponding territories. An important role in this must be played by soil scientists-meliorators.

The expansion of irrigated areas must be achieved by using the new techniques in the construction of irrigation systems and their exploitation. Covered channels must be used on soils susceptible to secondary salinization in order to eliminate water seepage. In time, water supply through pipes will be widely used, as well as irrigation by means of sprinkling installations or devices. With such methods of irrigation the soil could be supplied with only the amount of water it can retain and the hazard of rising ground water could be eliminated in certain cases, or reduced. In relation to this the need arises to revise the existing methods of evaluating soil-meliorative conditions for a number of regions, which were established earlier for irrigation by the old methods. Such a revision should also be made of other areas, where experience in irrigation is lacking, especially under conditions of the dry steppe zone, which differs considerably in its natural properties from the irrigated regions of Central Asia and the Trans-Caucasus. This work is extremely important and wide in scope.

The fulfillment of all the tasks facing agriculture requires great efforts and could meet with a number of difficulties, such as the shortage of cadres of soil scientists, having both a general and a very specialized training. The shortage of soil scientists who are properly trained to fulfill many practically important tasks is being felt even now. There are especially few soil scientists who are sufficiently acquainted with the requirements of an irrigated economy; such soil scientists as could conduct investigations needed for working out soil-meliorative irrigation projects, a fact which should cause concern even now.

The most important task of soil scientists, especially those working with scientific-research institutions, experimental stations, and agricultural management, is the wider introduction of the achievements of soil science into practical agriculture. Any scientific investigation plus any experiment on the improvement of soils and on the increase of their fertility can be considered as completed only when their results are introduced into production.

We must thoroughly study the material and resolutions of the January Plenum of the Central Committee of the Communist Party of the USSR, uncover and eradicate those shortcomings which hinder the further fruitful work of soil scientists in filling the needs of agriculture and the introduction of its results into practical agriculture.

ZONAL STUDY OF THE MINERAL FERTILIZER RATES AND LARGE-SCALE SOIL MAPS

P. G. NAYDIN and N. N. MIKHAYLOV, All-Union Scientific-Research Institute of Fertilizers and Agricultural Soil Science

The crucial question of the whole problem of fertilizers is the establishment of the rates of mineral fertilizers necessary for the creation of a definite yield level of one or the other crop. A proper solution of the problem of fertilizer rates is required in order for the government to regionalize mineral fertilizers according to individual natural-economic zones of the country. It is also necessary to substantiate the systems of fertilization in any particular crop rotation in each individual kolkhoz or sovkhoz.

In establishing the need of mineral fertilizers in the Soviet Union, optimum fertilizer rates must be determined.

By an optimum mineral fertilizer rate we mean such an amount of fertilizers which has to be applied per hectare of planting to ensure (in conjunction with a sufficiently high level of agricultural techniques) the planned yield of a given crop of a good quality with the least expenditure of fertilizer. Practical workers are most interested in the problem of the rate or amount of fertilizers: how much and what fertilizers must be added to this or that crop to ensure a definite level of crop yield.

By the amount of fertilizer (in contrast to the concept of the annual rate of fertilization) we mean that amount of the annual rate of fertilizer which is added to the soil using various methods of application (base fertilization during sowing and top-dressing) at a given farm, taking into account soil, crop rotation, and other associated agricultural conditions.

The initial data for judging the rates and amounts of mineral fertilizers are obtained from the general results of corresponding field experiments, conducted in previous years under various soil and climatic conditions. Thus, average rates of mineral fertilizers were set up to substantiate the scheme of the fertilizer requirement of the most important crops for the current 7-year plan and for the future. This was done for the benefit of the Soviet Union as a whole and for its individual economic regions.

The sharp increase in production and in the use of mineral fertilizers, called for by the 7-year plan, and the outlook for future years, set before us the task of revising a number of proposals and recommendations in relation to the rates and amounts of mineral fertilizers. The geography of the use of mineral fertilizers in our country will undergo considerable changes even by the end of the current 7-year plan. The use of fertilizers for food and forage crops will increase sharply; this increase will lead to great changes in the regional distribution of intensive fertilizer use. In relation to this, new large centers using mineral fertilizers will appear on the map of the Soviet Union, such as the center of the non-chernozem belt, the northwestern portion of the country, the Baltic republics, the Belorussian SSR, the forest and forest-steppe regions of the Ukrainian SSR, and Siberia and the Far East.

The available experimental material on the rates and amounts of mineral fertilizers is insufficient with respect to all crops in the eastern regions of the country (Far East Eastern Siberia, Kazakhstan, and Western Siberia). There is also insufficient material on many regions of the non-chernozem belt. There are almost no data on the rates of mineral fertilizers for corn in the non-chernozem belt and the forest steppe, and for winter crops with fallow. There is little data on fertilizer rates for all the regions under forage crops, but there are scattered data on meadow and pastures and perennial plantings (vineyards, gardens, and small-fruit patches). The problem of the rates of mineral fertilizers for crops which are considered to be the most studied in this respect, such as sugar beet and cotton, has become a debatable one in recent years. The resolutions of the joint session of the All-Union Lenin Academy of Agricultural Sciences and the Ukrainian Academy of Agricultural Sciences, which took place in Kiev in 1959, call for the expansion of experimental-research work on fertilizer rates. A similar proposal was made recently by a number of investigators with respect to cotton (10, 11, 15).

It must be noted that in the last 10-12 years little attention had been paid by scientific-research institutions to the problem of the study of the rates and amounts of mineral fertilizers. The organization of experimental work on the study of mineral fertilizer rates, zone-by-zone, had been planned before World War II. However, because of the war it had not been achieved on the scale planned (8, 12). The problem of the study of fertilizer amounts has become very important in our time because of the new, high requirements for the production of all agricultural crops. The necessity of revising the earlier established fertilizer amounts is also called for by the introduction into production of new methods of raising agricultural crops (square-hill and square sowing on furrow-plowed soil, plowing without a moldboard), and new methods of applying fertilizers (hill, row during sowing, and local applications of fertilizers).

In relation to the extensive work being conducted now on the construction of large-scale soil maps, the need arises for the full utilization of the results of this work in the practical application of fertilizers and, primarily, for the substantiation of fertilizer amounts (how much and what fertilizers must be used on a given soil variety in farms).

It must be noted that at the present time we do not have reliable theoretical methods of calculating fertilizer amounts necessary for obtaining a set yield of a given crop under definite natural and agricultural conditions, even though attempts at such calculations have been made repeatedly (5).

The characteristics of the chemistry, physical structure, and biological activity inherent in each soil variety, distinguished by modern genetic soil science, must also govern its specific reaction to the cultural-economic activity of man, and, in particular, to fertilization. However, on the basis of the present knowledge of the properties of soil and the characteristics of plants, we can draw only the most generalized conclusions on the composition and amounts of fertilizers to be added to the soil in a certain part of a field, truck garden, or meadow, to obtain the desired yield and quality of the crop grown. In this respect, the establishment of general geographical principles of the effect of fertilizers, depending on the properties of soils (of a given territory), by the method of geographical field experiments, is very promising. Using this method, together with properly organized experiments, one could determine how one soil variety differs from another with respect to the effect of fertilizers of a given composition, applied in a definite way. However, this solution to the complicated problem of the differential approach to the establishment of fertilizer rates (amounts) should not be compared to all the other methods of studying soil fertility.

To determine the way fertilizers act in relation to soil conditions, one requires the most complete information on the agronomically important properties of soils, which can be compared by means of the field method. Unfortunately, the agricultural-chemical characterization of soils, being compared by field experiments, is often incomplete and imperfect. The methodological difficulties in the organization of field experiments proper, conducted with the object of determining the regular relationship between soil conditions (or more precisely, between the complex of natural conditions) and the effect of fertilizers, should not be underestimated.

These difficulties are associated with differences in the agricultural setup of individual field plots and meteorological conditions, and with the different response of various agricultural plants to fertilizers.

Agricultural practices accompanying the use of fertilizers have a great influence on the natural characteristics of soil and change its productivity considerably. Differences in the agricultural setup and, primarily, in crops which had occupied a field prior to the experiment and its previous fertilization, have such a great influence on the effective fertility of the soil that two field plots completely identical with respect to soil genesis may react entirely differently to a fertilizer. And on the contrary, two different field plots with respect to soil genesis may react in the same way to the fertilizers applied under the influence of the same agricultural practices.

As we know, the introduction of perennial leguminous grasses into crop rotation on all soils changes the requirements of the following crops in fertilizers; in this case the effect of nitrogen fertilizers is weakened, while the effect of phosphorous and potassium fertilizers is increased. From the numerous examples which prove this pattern, let us give you as an illustration the results of only one pot experiment made at the Belotserkov Experiment Station (9), in which one and the same soil (fine clay loam, leached chernozem) showed a pronounced response sometimes to nitrogen, when sowing oat after grain crops, and sometimes to phosphorus when sowing oat after clover (Table 1).

Table 1

Influence of preceding crops on the change in the nitrogen and phosphorous requirements of the following crops (greenhouse experiments with oats)

Fertilizers	Oat yield, g per pot	
	After clover	Winter wheat
Control without fertilizer	10,6	13,8
P	30,7	15,0
PK	31,1	9,5
NPK	46,9	48,8

Note: Comma represents decimal point.

A large number of field experiments with grains, sugar beets, cotton, flax, and potatoes on various soils show the same pattern. The application of manure at the acceptable rates in practice, also cause a sharp change in the requirement of any soil in mineral fertilizers. Table 2 gives individual examples from long-term experiments with potatoes and sugar beets, which show that the application of manure sharply reduces the effectiveness of phosphorus and partly of potassium, while it hardly changes the effect of nitrogen fertilizers.

Similar results were obtained in a large

Table 2

Effect of phosphorous and nitrogen fertilizers against a background of manure and a background without manure

Experiment stations	Increment against a manure background, cntr/ha				Increment from superphosphate, cntr/ha (dos. of 30-60 kg/ha P_2O_5 without manure)
	N	P	NP	NPK	
Sugar beets					
Khar'kov	25	9	24	35	51
Sumy	21	15	30	56	53
Kuznets	40	2	54	64	
Potatoes					
Novozybkov	28	5	—	49	11
CES[a]	27	7	—	44	18
Kalugi	25	5	—	53	19
Orlov	31	18	—	55	27

[a] Central Experiment Station, All-Union Institute of Fertilizers and Agricultural Soil Science.

number of experiments not only with sugar beets and potatoes, but also with cotton, vegetable crops, food tubers, and spring and winter grain crops after fallow. In general, it must be concluded that manure is an excellent source of phosphorus and potassium as plant nutrients, and usually does not entirely meet the requirements of plants for nitrogen.

Weather conditions also cause a considerable change in the effectiveness of fertilizers on one and the same soil. Deviations from long-period averages often lead to rather considerable changes in the level of effective fertility of a given soil group or variety, and consequently to a change in the "average" effectiveness of fertilizers. We could give many pertinent examples. In one of our experiments on the sod-podzolic soil of the Central Experiment Station of the All-Union Institute of Fertilizers and Agricultural Soil Science at Barybino (Moscow Oblast') with various amounts of nitrogen fertilizers applied to spring wheat, we obtained sharply differing results in two years (1939 and 1940) only because of different weather conditions. In 1939, the spring was cold, which was typical for the Moscow Oblast'. As a result of weakened biological activity there were very little nitrates in the soil at the time of tillering of spring wheat. In 1940 the spring was unusually warm and the content of nitrates in the soil was two and one-half times as high at the time of tillering of wheat than in the preceding year. Correspondingly, the effectiveness of nitrogen fertilizers in 1939 was normal for the conditions at the Central Experiment Station of the All-Union Institute of Fertilizers and Agricultural Soil Science, while in 1940 it was sharply reduced (Table 3).

Table 3

Effect of nitrogen fertilization on podzolic soil depending on weather conditions, Central Experiment Station, All-Union Institute of Fertilizers and Agricultural Soil Science

Fertilizers	Yield of spring wheat grain, cntr/ha	
	1939	1940
O	8,4	20,3
PK	8,9	21,8
PK + N_{60}	16,8	24,1
PK + N_{120}	18,3	25,8
Mean daily temp. dur. sowing period (May), °C.	8,4	13,0
Nitrate nitro. during tillering per., mg/kg of soil	9,8	24,0

Note: Comma represents decimal point.

Of all mineral fertilizers, the most stable effect on chernozem soils is usually obtained by phosphorous fertilizers. However, as the results of long-term experiments show (Table 4), the magnitude of the effect of these fertilizers is subject to considerable fluctuations depending on weather conditions.

Sharp reductions in the effect of phosphorous fertilizers on winter grain crops occur in years with sub-normal (drought years) and excessive summer precipitation (leading to lodging on fertilized plots).

Differences in the agricultural setup and in

Table 4

Effect of phosphorous fertilization on chernozem soils depending on weather conditions

Experiment stations	Increment of winter wheat yield grain, cntr/ha		
	Average for 20 yrs.	Least	Maximum
Shatilov	4,4	0,6	7,9
Khar'kov	4,5	—0,9	9,2
Sumy	4,0	1,5	14

Note: Comma represents decimal point.

meterological conditions in individual field plots, plus the biological differences between plants in field experiments cannot be eliminated; however it is possible and necessary to determine the magnitude of their effect on the action of fertilizers. This requires geographical field experiments, which would allow one to determine the relationship between soil conditions (natural) and the effect of fertilizers (in particular, various amounts of fertilizers) in the area studied. Such comprehensive long-period experiments (not less than 3 years) under crop rotation or individual crops under rotation, including corn, which differ sharply in their response to fertilizers (among the most important and widespread in a given agricultural region), must be conducted according to coordinated schemes. The experimental schemes must necessarily provide for the determination of the effect of various amounts of fertilizers against a background of agricultural practices which would strongly affect the effective fertility of the soil. These practices could include an alternation of plants (first of all the influence of perennial grasses must be considered) which would precede or accompany the application of mineral fertilizers, manuring (or green manuring, the application of peat, etc.), irrigation, and liming of acid soils.

Before each experiment is begun, the soil conditions of the plot must be studied thoroughly. Later, the experiment must be accompanied without fail by the study of all the important environmental conditions (which can be subject to analysis) where the plant develops, and the reaction of the plant itself to the fertilizers. In our huge country with its exceptional variety (with respect to natural conditions and production) of agricultural land uses, many hundreds of geographical experiments are needed. The expected increase from fertilizers forces us to accelerate the development of the governmental system of geographical experiments with fertilizers. Considering the modern state of the organization of experimental work, we must develop this system by gradually enlisting the cooperation of the best-equipped large scientific-research institutions, particularly in areas where chemical reaction is of especially great importance.

In addition to a single governmental system of geographical experiments with fertilizers, former experiments with fertilizers must be resumed. In addition, new mass experiments with fertilizers must be organized on the scale of individual republics and regions to determine the principles of the action of fertilizers in relation to local natural and production conditions. These local geographical experiments must also be based on a thorough study of soil conditions in each individual experiment.

In this respect we must take note of the work conducted at the Armenian Scientific-Research Institute of Agricultural Chemistry and Soil Science, which started its mass field experiments with fertilizers in the kolkhozes of the republic and embraced all the major varieties of cultivated soils. In 1960, the Institute started about 100 experiments in kolkhozes, having conducted a thorough soil survey in each experimental area.

The All-Union Lenin-Order Scientific-Research Institute of Cotton Growing (SoyuzNIKHI) plans to organize by 1961 mass field experiments with fertilizers through the agricultural-chemical laboratories of the republics. It also plans to conduct simultaneously agricultural-chemical soil analyses of the content in the soil of mineral nutrients available to plants.

In establishing the optimum rates and amounts of mineral fertilizers, it is necessary to utilize as fully as possible the agricultural-chemical indices of the amount of nutrients available to plants, differentiating them for various soils and various crops. The use, for this purpose, of indices of the content of available nitrogen compounds, phosphorus, and potassium in the soil is complicated by the imperfection of the methods of determining them. However, even with these methods it is possible to use the indices for the foregoing purposes. In this respect, the practices in foreign countries must be considered.

In the German Democratic Republic cultivated soils are subdivided on the basis of agricultural-chemical analysis of the content of available forms of phosphorùs (method of Egner-Rim) into groups with a high, moderate, and low supply of phosphorus. When these groups are determined, the texture and acidity (pH) of the soil are taken into account in addition to its content in available P_2O_5. Depending on the amount of phosphorus in the soils, the soil scientists and agricultural chemists of the German Democratic Republic make their recommendations to the practical men on the amounts of phosphorous fertilizers to be added to individual crops. The amounts of potassium fertilizers are also determined by the amount of potassium in the soils (1, 2).

Investigations conducted in other Western European countries (Sweden, Denmark, and Holland) show that there, also, the content of available nitrogen compounds, phosphorus, and potassium in the soils is considered when making recommendations on the amounts of fertilizer. The Chief of the State Soil Laboratory of Denmark, Bondorff (16), has established, on the basis of extensive field-experiment data, a very reliable correlation between the content of available potassium and phosphorous compounds in Danish soils and the effect of potassium and phosphorous fertilizers in field experiments.

Investigations conducted in the United States of America indicate that there is a definite correlation between the content of available phosphorous compounds in the soils of the United States and their response to phosphorous fertilizers (17, 18). As in a number of Western European countries, recommendations on the rates of application of phosphorous and other types of mineral fertilizers are given in the United States with differentiations, taking into account the content of available nitrogen compounds, phosphorus, and potassium in the soils. The United States has already constructed maps of the supply of available compounds of N, P, and K in the soils for individual states, and for the country as a whole. These materials are used when working out recommendations on fertilizer rates.

Experience gained in foreign countries shows that in spite of imperfect methods, it is still possible to use the data from agricultural-chemical analyses for giving differential instructions on amounts of mineral fertilizers for individual agricultural crops or groups of such crops. The instructions would depend on the supply of available compounds of the major nutrients in the soil.

A study of foreign materials on these problems also shows that the effective use of data from agricultural-chemical soil analyses requires numerous field experiments with mineral fertilizers under various natural conditions in various soils. Thereby, it is possible to establish a correlation between the indices of the agricultural-chemical characteristics of soils and the effect of fertilizers on the yield of agricultural plants on various soils under field conditions.

Experimental work on the establishment of amounts of mineral fertilizers is very limited in our country, and is little related to work on large-scale soil maps, as well as to the development and use of methods of agricultural-chemical control of the proper use of fertilizers.

The methodological instructions of the All-Union Institute of Fertilizers and Agricultural Soil Science on the compilation and use of soil maps of kolkhozes and sovkhozes of the RSFSR, published in 1959 (7), call for the construction of cartograms of the supply of available phosphorous and potassium compounds in the soils. But recommendations on the practical use of these indices are very schematic because there is not enough experimental data on the effect of phosphorous fertilizers, for instance, on soils with a definite content of available phosphorus. There are no recommendations on fertilizer amounts on large-scale maps which had been compiled in 1960 by the Turkmen Agricultural Institute, even though cartograms of the content of available phosphorus in the soils are appended to these maps.

By the joint effort of soil scientists and agronomists, soils with various contents of available phosphorus have been determined now for the irrigated regions of Central Asia, and an interrelationship has been established between its content and the effectiveness of phosphorous fertilizers. Investigations (All-Union Institute of Fertilizers and Agricultural Soil Science, the All-Union Lenin-Order Scientific-Research Institute of Cotton Growing, and the Tadzhik Agricultural Scientific-Research Institute) showed that the application of phosphorous fertilizer to cotton gives a stable effect only on soils having an available phosphorous content of less than 15-25 mg/kg P_2O_5. On sierozem, however, having a P_2O_5 content of more than 45-60 mg/kg, the application of phosphorous fertilizers, even against a background of considerable amounts of nitrogen, does not ensure an increase in the yield of raw cotton. This is well-illustrated by the data of Chumachenko (14). In relation to similar material of other investigators (3, 6, 13) a discussion arose on whether there are many soils with a high content of available phosphorus ("phosphated") in the irrigated cotton-growing areas.

We believe that investigators and practical men should pay attention to another, more important fact. The materials in the foregoing article by Chumachenko show that an increase of the amount of phosphorus exceeding 70 kg/ha P_2O_5 does not increase the yield of raw cotton in any soil group, including the group of soils with the least available phosphorous content (18-28 mg P_2O_5 per 1 kg of soil). It must be noted that with those phosphorous amounts that are usually used in field experiments with a great number of crops, an increase in the amount of phosphorus either does not produce an increase in yield, or increases it insignificantly and thus, is not justified.

This is especially clearly shown by the results of long-term experiments with sugar beets, a crop which is very responsive to phosphates, especially on chernozems. The results of long-term experiments by the All-Union Institute of Fertilizers and Agricultural Soil Science on the thick chernozem of the Sumy experiment station, in which all the proper field-experiment conditions were fulfilled and where fertilizer was applied in rows to sugar beets and a moderate amount of manure, was used in each crop rotation (4), are shown in Table 5. An increase in the amount of phosphorus did not produce an increase in the yield of beets against any of the three different nitrogen-potassium backgrounds.

The necessity of greatly expanding experimental work for the determination of economically optimum rates of fertilizers for the main agricultural crops, in close agreement with work on the compilation and use of large-scale soil maps, is quite obvious. Conducting experimental investigations on fertilizer rates and amounts in conjunction with a verification and elaboration of methods of agricultural-chemical control must be the main purpose in the study of fertilizers in the near future. The main attention in this work must be given to phosphorous fertilizers. The data obtained in the last 10 years on phosphorus in the soil, on the effect of phosphorous fertilizers in plots having been fertilized for a long time ("phosphated"), and other materials, show how necessary it is to

Table 5

Amounts of fertilizer during 7-crop rotation

Fertilizers	P_2O_5 in the base fertilizer, kg/ha		Sugar beet yield, cntr/ha (13-year average)
	Per rotation	Per 1 ha of field	
Background of $N_{10}P_{20}K_{10}$ in rows of beet	—	—	232
Manure, 20 metric tons/ha	—	—	255
Manure, 20 m t/ha + $N_{75}K_{30}$	75	10,7	275
" " "	150	21,4	278
" " + $N_{75}K_{150}$	150	21,4	302
" " "	270	38,5	300
" " $N_{150}K_{285}$	210	[illegible]	316
" " "	420	360,0	314

Note: Comma represents decimal point.

revise the earlier-formed opinions on the nature and magnitude of the fixation of phosphorous fertilizers in various soils, on the coefficient of utilization of phosphorus, and on the necessity of using phosphorus in amounts exceeding its removal from the soil by agricultural crops. We should begin the establishment of a wide series of experiments, first of all, on the study of the optimum amounts of phosphorous fertilizers, and simultaneously conduct investigations on the verification and elaboration of agricultural-chemical methods of determining the available phosphorous compounds in the soil.

This work will allow us to determine the main principles of the effect of fertilizers in relation to soil-climatic and agricultural factors.

Received November 19, 1960

BIBLIOGRAPHY

1. ANDREYEV, A.A. 1959. Agriculture. Sel'khozgiz.

2. BARANOV, P.A. and N.P. KARPINSKIY. 1957. Use of fertilizers in the German Democratic Republic. Sel'khozgiz.

3. BALYABO, N.K. and S.G. VASIL'YEVA. 1960. Problem of the construction of large-scale soil maps in the irrigated cotton zone. Khlopkovodstvo. No. 7.

4. GORSHKOV, P.A. 1958. Combination of manure and mineral fertilizers, amounts, and ratios of mineral fertilizers in grain-beet crop rotation. Sbornik trudov Sumskoy gosudarstvennoy opytnoy stantsii. Kiev-Sumy.

5. ZHURBITSKIY, Z.I. 1958. Nutrient requirements of plants as a basis for the use of fertilizers. Izd. Akad. Nauk SSSR.

6. MALINKIN, N.P. 1957. Distribution of fertilizers in cotton crop rotations in Central Asia. Sbornik nauchnykh rabot po primeneniyu udobreniy pod khlopchatnik. SoyuzNIKHI, Tashkent.

7. Methods of compiling and using soil maps in kolkhozes and sovkhozes of the RSFSR. 1959. VASKHNIL-VIUA, Moscow.

8. NAYDIN, P.G. 1941. Fertilizer rates. Khimizatsiya sotsialisticheskogo zemledeliya. No. 2.

9. NAYDIN, P.G. 1930. Nitrogen fertilizers in the crop rotations on the right bank of the Ukraine. Kiev.

10. PROTASOV, P.V. 1959. Fertilizer rates for cotton. Odobreniye i urozhay. No. 11.

11. POPOV, G.P. 1959. Possibility of increasing production and the effectiveness of fertilizers in Uzbekistan. Udobreniye i urozhay. No. 11.

12. STANKOV, N.Z. 1939. Organization of a geographical network for experiments with fertilizers. Khimizatsiya sotsialisticheskogo zemledeliya. No. 10-11.

13. SOKOLOV, A. V. 1958. Supply of available phosphates in soils and their accumulation when applying phosphorous fertilizers. Pochvovedeniye, No. 2.

14. CHUMACHENKO, I. N. 1959. Available phosphate content in the calcareous soils of Central Asia and the effectiveness of phosphorous fertilizers in irrigated cotton-growing regions. Pochvovedeniye, No. 5.

15. CHUMACHENKO, I. N. and V. S. KORNIYENKO. 1958. Effectiveness of phosphorous fertilizers depending on the saturation of soils with phosphates. Odobreniye i urozhay. No. 2.

16. BONDORFF, K. A. 1956. Résultats des analyses du sol: leur interprétation et leur application. Organisation et Radionalisation de l'analyse des sols. OEEC, Paris.

17. BINGHAM, F. 1949. Soil test for phosphate. California Agr. 3(8).

18. ENSMINGER, L. E. and H. W. LARSON. 1944. Carbonic acid soluble phosphorous and lime content of Idaho soils in relation to crop response to phosphate fertilization. Soil Science.

CERTAIN METHODS OF RATIONALLY UTILIZING SOIL MOISTURE IN TEA PLANTATIONS

M. K. DARASELIYA, All-Union Scientific-Research Institute of Tea and Subtropical Crops

In spite of plentiful precipitation in the subtropical regions of Western Georgia, the extremely uneven seasonal distribution and the intense uptake by vegetation necessitate the development of measures for the regulation of the water regime of soil. Under conditions of a flat relief, these measures must be directed toward the diversion and removal from plantations of the excess water from autumn and winter precipitation, which accumulates because of the poor permeability of the soils and insufficient surface runoff. During the spring-summer months the main problem is how to utilize soil moisture, rationally, and in many cases how to supplement precipitation by irrigation. The latter practice-irrigation — sprinkling, is especially critical in the eastern regions of Georgia, such as Tsulukidze, Tskhaltubo, and other areas in Imeretia.

Precipitation in the subtropics is characterized by heavy showers, which occur mostly in autumn.

This type of precipitation leads to an unstable soil-water regime, often creating a deficiency in soil moisture for the subtropical plants, especially tea. This is especially pronounced on red earth soils, which are found in hilly terrain. Because of their high porosity and permeability, and also because of intense percolation, often reaching 20%-30% of the precipitation, the gravitational water in red earth soils drains rapidly, and the favorable water to air ratio in the soil is disturbed by the decrease in moisture.

Long-term investigations show that the amount of moisture in the soil at the beginning of the growing period is close to its water holding capacity. Soon the moisture content in the soil decreases sharply because of the deficiency in precipitation, especially in April and May. This decrease unfavorably affects the formation of shoots in the tea plants.

In this respect, the conditions are slightly more favorable in subtropical podzolic soils. Even though there is less precipitation here during the growing period than in the red earth zone, its loss at the surface and from percolation is less intense. This is because of the poor permeability of the lower part of the soil profile where water often stands, forming a water layer (temporary water table). The frequency of the formation of a temporary water table is rather high, as our observations in the past years showed, and the water stands 5-10 days, depending on conditions. Such a situation, except for cases of excessive moisture, promotes more complete utilization of precipitation by agricultural plants.[1] It must be added that with the comparatively small difference between the minimum moisture capacity of podzolic soils and red earth, the percent of non-readily available moisture in podzolic soils is two times smaller than in the red earths. Thus, the wilting moisture of subtropical podzolic soils is about 10%-11%, while that of red earths reaches 21%-23%.

Thus, the amount of moisture for tea plants on subtropical podzolic soils is not lower, in spite of the considerably lower precipitation amounts, than on the red earths of slopes, which receive more precipitation.

The observational material collected by us for many years on the water regime of subtropical soils shows that moisture in them rarely drops below the critical moisture for plants, i. e., down to wilting moisture.

This sharp decrease in moisture is often observed only in the upper soil layers, which are subject to drying as a result of the physical evaporation of moisture, and occurs very rarely through the entire root zone of the soil. The moisture content in this layer of the soil is usually below minimum moisture capacity during the growing period, but it is always above wilting moisture, except in the surface layer. Such moisture conditions, according to the statements of Veihmeyer[2] and his followers, must ensure a normal moisture supply to plants.

However, the investigations conducted by us since 1933 did not confirm the statements of Veihmeyer as far as tea is concerned. These investigations as well as earlier ones, which established the differential availability of various parts of soil moisture for plants, showed a physiological deficiency of moisture, and lead us to the conclusion that tea plantations need irrigation. This fact was proved by field experiments conducted by the Institute for Tea from 1936-1938, and was confirmed by our experiments as well as production experiments conducted in the Achigvar tea sovkhoz from 1949-1957 on the sprinkling irrigation of tea plantations.

---

[1] Nevertheless, when establishing a tea plantation the compacted layer must be broken up (killifered) if it is less than 70 cm deep.

[2] F.J. Veihmeyer. Hilgardia, No. 2, 1927.

In spite of the foregoing statements on the periodic deficiency of soil moisture and the effect obtained from the sprinkling of tea plantations, we cannot assert that all the means for using the amount of precipitation falling in the regions studied, are utilized.

Let us cite several examples. According to the amount of precipitation, 1956 can be considered as a year with sufficient moisture; the amount of precipitation was 900 mm during the growing period (Anaseuli). However, the effectiveness of this precipitation differed depending on the state of the plantations. Thus, one of the plantations gave a high yield of tea leaves, which exceded six times the yield from another plantation of the same age. To produce the green foliage, the low-yield plantation consumed 80 mm of water per 100 kg of leaves, while the high-yield plantation consumed only 12.5 mm.

The causes for this big difference in the productive utilization of precipitation are primarily attributable to soil conditions, and to the complex of measures taken to increase the fertility of the soil, to improve the state of the plantation, and to increase the size and leafiness of tea plants (Table 1).

It must be noted that the plantations with different yields shown in Table 1 are versions of the same experiment, where the fertility of the soils under initially equal soil conditions changed considerably when the plantations were established (because of the different practices taken in each experimental treatment), so that the productivity of the plantation changed. As a result of the agricultural practices used, the humus content increased up to 6% in one case (the initial humus content was 4%), and up to 7.6% in another case. The content of easily available P_2O_5 increased correspondingly.

The development of the plants, their height, width, and leafiness, and consequently the productivity of a plantation, depend on the increase in soil fertility. A clear relationship is found between the productivity of plantations and the water consumption of tea plants; the latter drops sharply as the productivity of a plantation increases. Thus a yield of 1060 kg/ha requires 69 mm of precipitation per centner of green tea leaves, while a yield of 10700 kg/ha requires only 8 mm.

Thus, the utilization of precipitation is directly related to soil fertility and the state of the plants. Creating such plantations requires a complex of practices, including a system of fertilization, and a system of pruning and harvesting leaves directed toward the creation of good foliage and a favorable density of plants in the plantations. The better the crown of the plants is developed and the more foliage the shrubs have, the denser the plants become and the better they use the moisture and the nutrients in the soil. However, a space of 25-30 cm must be left between the rows of shrubs to permit machines and workers to pass.

With a plantation density which provides for the shading of about 85% of the space between

Table 1

Relationship between the fertility of soils, productivity and the water consumption of tea plants

Nature of tea plantations	Depth, cm	Humus, %	P_2O_5 soluble in citric acid, mg/kg of soil	pH	Character of the devel. of the shrub crown, cm		Yield, kg/ha	Amt. of precip. mm per each cntr. of tea leaf
					Height	Width		
Low productivity	0—15	4,0	45,0	4,7	54	74	1 060	69,6
	15—30	3,0	36,4	4,7				
	30—45	2,3	24,6	4,5				
Highly productive if the agricultural practices for tea are followed	0—15	6,0	388,3	4,1	92	128	7 750	10,8
	15—30	3,6	151,4	4,1				
	30—45	2,6	63,8	4,0				
Extremely productive with liquid manure added in addition to other agricultural practices	0—15	7,6	446,1	4,2	94	134	10 700	8,0
	15—30	5,0	156,0	4,1				
	30—45	2,6	43,5	4,2				

Note: Comma represents decimal point.

Table 2

Moisture of red earth, % (average monthly values), Anaseuli, 1957

Depth, cm	May		August	
	Plantations with shaded spaces between rows, %			
	85	50	85	50
0—10	36,9	29,9	32,5	25,6
10—20	39,3	29,7	34,4	26,4
20—30	39,3	32,0	36,3	26,9
30—40	39,0	34,6	34,0	28,5
40—50	41,5	34,4	34,0	28,3
50—60	43,8	36,6	35,0	30,0
60—70	43,4	36,2	36,2	33,6
70—80	41,1	34,5	38,3	35,3
80—90	46,3	34,2	42,0	37,1
90—100	50,3	34,0	40,6	37,0
0—100	42,5	33,7	36,3	30,8

Note: The minimum moisture capacity of these soils in the layer from 0-60 cm is 45%-47%.

Note: Comma represents decimal point.

the plant rows, water losses from the soil surface are reduced sharply. Comparative studies on evaporation from the soil surface showed that in plantations with poorly developed shrubs with crowns shading only up to 50% of the soil surface between the rows, water losses during the growing period increase by more than 150-200 mm as compared to plantations having well-developed shrubs, shading 85% or more of the surface between the rows.

To illustrate the foregoing, let us discuss certain data on soil moisture in two plantations varying in plant development, crown foliage, and the shading of the areas between the rows (Table 2).

The plantations being compared are located next to each other and have similar relief and soils, but in one of the plantations the soil is fully shaded by the crowns of the plants, while in the other plantation the space between the plant rows of a width of 70 cm, or 50% of the area, is not shaded. As the data in Table 2 show, the effect of shading is quite great. The difference in moisture in the upper 1 m of soil was 8.8% in May and 5.5% in August, or, if converted to precipitation about 88 mm of water in the first case and 55 mm of water in the second case.

It must be noted that the importance of the enclosure of crown of plants in plantations is not limited only to the depression of evaporation from the soil surface. With good foliage and enclosed crowns, a larger percentage of the leaves is shaded and less exposed to the influence of direct solar radiation and overheating. Leaf temperature measurements showed that it varies greatly depending on solar radiation, the arrangement of the leaves, the angle of inclination, wind direction, etc. The leaves that are at the surface of the crown and open to direct solar radiation always have a higher temperature than those in the remaining part of the crown which are shaded. This is illustrated by Table 3.

As the averages from many observations show, the difference between the temperature of those leaves which are open to solar radiation and those which are shaded reaches almost 5°C. The same difference was found from measurements made in the lateral part of the crowns.

A reduction in leaf temperature apparently promotes a reduction of water losses by plant transpiration, which creates better moisture economy in the soil and in the tea leaves. Numerous observations show that the higher the soil moisture, the higher the moisture content is in tea leaves; in our case the difference in

Table 3

Temperature of tea leaves, °C at 1-2 p. m.

No. of observation days	At the surface of the crown		Lateral part of a shrub exposed to the southwest		Inside the crown 5 cm from its surface	Air temperature, °C
	Open to solar radiation	Shaded leaves	Open to solar radiation	Shaded leaves		
1	30,4	27,2	31,0	26,1	26,7	28,5
2	31,5	26,2	31,2	25,3	25,6	28,0
3	31,7	25,8	30,5	25,1	25,6	—
Average	31,2	26,4	30,9	25,5	26,0	—

Note: Temperatures were measured 5 times.

Note: Comma represents decimal point.

the moisture of tea leaves in the two plantations compared reaches 2% and more. It must also be noted that the relative humidity of air above the crowns of shrubs in enclosed plantations with good foliage is 2%-4% higher than in those with poorer foliage and wide open spaces between the rows.

All this creates conditions for the more economical consumption of moisture. As experiments in past years showed, an increase in foliage promotes a certain increase in total water consumptions, but its use per unit leaf surface decreases considerably, i. e., the productiveness of transpiration increases. This, as we mentioned earlier, is the result of the change in phytoclimate in enclosed plantations as compared to plantations with open spaces between the rows.

The data obtained by us show that the greatest uptake of soil moisture by the shrubs occurs in the upper 0-30 cm of soil. This is attributable to the fact that the main mass of fine roots of the tea plants is concentrated in the layer down to 20 cm. The concentration of roots in the surface layer occurred as a result of the action of mineral fertilizers which were applied to a depth of 10-12 cm. However, the root system of shrubs having never received fertilizers has the form of an inverted cone, sharply differing from the roots of fertilized plants which are mushroom-shaped. This concentration of roots in the upper soil layer is unfavorable and must be eliminated by all possible means, including another method of application of fertilizers.

The investigations conducted by us showed that the surface development of the root system is undesirable. The roots must develop throughout the depth of the cultivated soil layer in order to use it to the maximum, in particular, utilize the stored moisture in the soil. There is enough water in the lower soil layers even during dry periods, but this water is not readily available to the tea plant having a surface root system. If the roots of a tea plant would develop throughout the cultivated layer, then they would be able to use the water and nutrients from the lower soil layers during dry periods and give higher yields.

To determine the influence on tea yield of the deep application of the important nutrient — phosphorus, we made special experiments on a 20-year old,[3] non-fertilized tea plantation, plowed to the following depths: 1) 35-40 cm with the addition of phosphorus to the 0-35 cm layer; 15 cm with the addition of phosphorus to the 0-15 cm layer; and 35-40 cm with the addition of phosphorus to the 0-15 cm layer.

Each experimental plot was supplied with: 1000 kg P_2O_5 per ha in the form of superphosphate, which comprised an 8-10 year rate; potassium at a rate of 150 kg K_2O per ha, applied to the same depth as the phosphorus; and nitrogen in the form of ammonium sulfate at an annual rate of 200 kg/ha, applied to a depth of 5-6 cm.

The results of the experiments (Table 4) showed that when P_2O_5 was applied to a depth of 0-35 cm the soil remained well-supplied for 6 years to a depth of 30 cm and deeper.

The root system was studied in 1948, i. e, before the experiment was begun, and in 1958, 5 years after the experiment was initiated. Three

Table 4

Content of phosphoric acid in the soil (P_2O_5 soluble in citric acid) in relation to cultivation depth and application of phosphorous fertilizers (mg/kg of soil)

Depth, cm		Layers, cm	Years					
Soil cultivation	Phosphorous application		1949	1950	1951	1952	1953	1954
35—40	0—35	0—15	166,0	119,0	157,3	226,0	180,2	128,5
		15—30	126,6	101,1	112,5	133,9	104,6	109,7
		30—45	45,0	60,0	87,5	91,0	95,7	100,8
15	0—15	0—15	200,0	117,3	200,0	168,8	145,1	160,7
		15—30	30,0	54,1	78,3	80,7	74,4	67,1
		30—45	17,0	31,4	60,5	56,2	Trace	
35—40	0—15	0—15	133,2	107,4	166,5	127,8	122,7	109,5
		15—30	33,5	90,1	132,6	98,4	87,2	66,2
		30—45	24,9	65,2	90,2	94,0	Trace	

Note: Comma represents decimal point.

---

[3] The soil was cultivated in a space of 60 cm between the rows after the shrubs had been severely pruned.

Table 5

Distribution of the root system of tea in soil according to layers (in % of the total weight of roots) in relation to phosphorous application to various depths

Depth, cm		Before beginning of the experiment		Fifth year after experiment started
Soil cultivation	Phosphorous application	Layers, cm	1948	
35—40	0—35	0—10	30,4	37,0
		10—20	24,5	27,3
		20—30	23,5	31,4
		30—40	14,5	2,5
		40—50	4,9	1,1
		50—60	1,9	0,7
			99,7	100
15	0—15	0—10	30,4	53,6
		10—20	23,9	27,7
		20—30	22,3	13,1
		30—40	16,7	2,7
		40—50	4,8	2,4
		50—60	1,8	0,2
			99,9	99,7
35—40	0—15	0—10	26,1	52,4
		10—20	37,0	18,3
		20—30	22,0	17,7
		30—40	12,1	9,1
		40—50	1,8	2,0
		50—60	1,0	0,4
			100	99,9

Note: Comma represents decimal point.

plants were taken from each plot for study. The results are given in Table 5.

In 1948, i. e., before the experiment was initiated, the roots in all plots were similarly developed, namely: they were developing uniformly in the upper 40 cm, while, below, the amount of roots decreased sharply.

A study of the root system after phosphorus had been applied for 5 years showed first of all that the general root mass increased considerably where phosphorus was applied deep (in the layer from 0-35 cm), but their distribution had hardly changed at all. Secondly, it was shown that the root mass moved into the upper layer of the soil where phosphorus was applied at the surface to the layer from 0-15 cm deep.

The experimental plantation was established in 1929. The 20-year old shrubs have formed a root system which is not very responsive to change. The influence of the deep application of phosphorus was pronounced in this plantation, especially in the layer at a depth from 20-30 cm. This layer contained 31.4% of the roots, while the same soil layer in the other plots where phosphorus was applied to a depth of 15 cm contained only 13.1% and 17.7% of the roots. The effect of the deep application of phosphorus on the development of roots in the deeper layers of the soil probably would have been greater if we had conducted our experiment in a younger tea plantation, where the root system of the plants is not formed as in our experimental plot. From this it follows that the root system of tea develops normally into the deeper layers of red earth soil if these layers have a sufficient amount of nutrients. If, however, fertilizers are applied only to the upper layer, the roots system of a tea shrub will develop primarily in this layer. As was to be expected, the deep application of phosphorus had a positive effect on the yield of green tea leaves.

If one should compare the first and third experimental treatments in which the soil was plowed to the same depth (40 cm), but the phosphorus was applied to different depths, Table 6 shows that where phosphorus was applied deeply the yield in 1950 was considerably higher (2212 kg/ha) than where phosphorus was added

Table 6

Yield of tea leaves in relation to depth of phosphorous application (average from 3 tests)

Depth, cm		Former assessment (1948)	Years					Average from 1950-1956
Soil cultivation	Phos. application		1950	1951	1952	1953	1954	
0—40	0—35	494,0[a] 93	2212,0 119	2926,0 104	3738,0 122	4941,0 109	4556,0 122	3921,0 116
15	0—15	543,0 102	2218 120	3009 107	3453 112	4479 99	3616 97	3544 104
0—40	0—15	532,0 100	1851 100	2792 100	3085 100	4525 100	3714 100	3400 100
Precipitation, mm from Apr.-Sept.		1076,0	695,5	1007,6	620,4	684,4	634,6	

[a] In kg/ha in the numerator; in % in the denominator.

Note: In contrast to other years 1953 was characterized by an even monthly precipitation distribution, which was favorable to the normal growth of tea plants.

Note: Comma represents decimal point.

at the surface (1851 kg/ha). In 1950 the yield in the plot to which phosphorus was applied deeply was 19% higher than in the plot with a surface application of phosphorus.

In the plots where phosphorus was applied to the same depth of 15 cm, while the soil was cultivated in one case to a depth of 15 cm and in the other case to 40 cm, the yield in 1950 decreased to 20% because a large number of roots was damaged during the deep cultivation of the soil; this had a negative effect on the yield of green tea leaves. In the following years the yield increased generally and was better in the plot where phosphorus was applied deeply. The effectiveness of the deep application of phosphorus increased in dry years, for instance in 1952 and 1954 when there was little precipitation during the growing period.

Thus the deep application of phosphorus caused an increase in the yield of green tea leaves, which reached in individual years up to 22% as compared with the plot where phosphorus was added to the surface layer.

Prior to the experiment, the plot to which phosphorus was applied later deeply yielded, according to previous data, 7% less tea than the control plot. We therefore assume that the deep application of phosphorus resulted, during the 7 years the experiment lasted, not in an average 16% increase in yield, as shown in Table 6, but in a 23% increase, if the previous data are taken into account. This increase in yield occurred because of the deeper and more uniform distribution of roots resulting both from the deepening of the root system and the uptake by the tea plants of phosphates and moisture from the deeper soil layers.

At present it is difficult to accomplish the deep application of phosphoric acid fertilizers because of the lack of appropriate machines. However, such an application of fertilizers must be obligatory when establishing new tea plantations.

The foregoing material was obtained for red earths, in which P_2O_5 has a great effect on the development of the root system. This effect must be determined for other soils in which the fixation of P_2O_5 is weaker.

Conclusions

1. The formation of a wide, well-foliated crown in tea plants, which shades not less than 85% of the space between the rows, creates favorable conditions for the utilization of soil moisture.

2. The development of the root system of a tea plant depends greatly on the depth of appli-

cation of phosphorus and other nutrients. A deeper application of phosphorus (to red earths) promotes the deepening of the roots system of the tea plant, and improves conditions for the utilization of moisture and phosphates in the lower soil layers, which leads to a considerable increase in yield, whereby this effect is stronger in dry years.

Received June 14, 1960

NUTRIENT REGIME OF THICK CHERNOZEMS IN THE FOREST, THE STEPPE, AND IN A PLOWED FIELD IN THE KURSK RESERVATION AREA

D. M. KHEYFETS, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

The purpose of our work is to find differences in the nutrient regime of thick chernozems under the influence of various plant communities for the basis of applying fertilizers in this soil group.

In studying the foregoing problem we took soil samples of virgin chernozem from the area of the Central Chernozem State Reservation in an uncut steppe, from the "Dubrashin" forest (which we will call "D" forest), the Petrin forest ("P" forest), and from the old plowland of the former Petrin sovkhoz,[1] located near the Petrin forest. The samples for greenhouse experiments were taken from the soil layer 0-20 cm deep, while for the analytical work they were taken throughout the profile to a depth of 130-140 cm. A short description of the soils which served as samples in our work is given by the soil scientist Afanas'yeva (1).

1. The soil from the "Dubrashin" forest is a thick, fertile, fine clay loam chernozem on loess-like clay loam, slightly modified by the forest vegetation. The place from which the sample was taken was a small area surrounded by young oaks; the area was cleared of litter and of the upper 1.5 cm of soil. Effervesces from HCl at a depth of 125 cm.

2. The soil from the uncut steppe is a thick, fertile, fine clay loam chernozem on loess-like clay loam. Effervesces from HCl at a depth of 110 cm.

3. The plowed soil (clover field) is a thick, fine clay loam, leached chernozem. Old plowed farmers' land. Effervesces from HCl at a depth of 125 cm.

4. The soil from the Petrin forest is a thick, fine clay loam chernozem. Effervesces from a depth of 120 cm. (Alongside the sovkhov.) It is

Table 1

Humus, nitrogen, and potassium content in the thick chernozem of the Kursk Reservation area, % absolutely-dry soil

Depth, cm	Place samples were taken											
	Steppe	"D" forest	"P" forest	Plowed	Steppe	"D" forest	"P" forest	Plowed	Steppe	"D" forest	"P" forest	Plowed
	Humus				Total nitrogen				Exchangeable potassium[a]			
0—10	9,1	9,2	9,0	6,6	0,443	0,510	0,458	0,406	0,0179	0,0210	0,0204	0,0166
20—30	6,1	5,1	6,8	5,7	0,285	0,320	0,358	0,293	—	—	—	—
40—50	4,6	3,7	6,1	5,2	0,229	0,192	0,214	0,241	—	—	—	—
60—70	3,3	2,5	4,5	4,2	0,195	0,161	0,104	0,169	—	—	—	—
80—90	2,2	2,0	2,1	3,3	0,140	0,102	0,102	0,181	—	—	—	—
100—110	2,3	1,5	1,8	2,6	0,077	0,096	0,102	0,102	—	—	—	—
130—140	0,7	1,0	1,2	—	—	0,061	0,102	0,091	—	—	—	—

[a] The data are given in % of K_2O in the layer from 0-20 cm.

Note: comma denotes decimal point.

---

[1] At the present time the Petrin sovkhoz is part of the area of the Kursk Oblast' experiment station.

Table 2

Total phosphorous content in the thick chernozem of the Kursk Reservation area

Depth, cm	Place where samples were taken			
	Steppe	"D" forest	"P" forest	Plowed
0—10	0,168	0,190	0,194	0,165
20—30	0,136	0,133	0,167	0,148
40—50	0,112	0,130	0,140	0,126
60—70	0,109	0,150	0,127	0,129
80—90	0,085	0,140	—	0,131
100—110	0,078	0,120	0,101	0,090

Note: comma denotes decimal point.

Table 3

Content of soluble phosphates in thick chernozem (according to data obtained by various methods). P_2O_5 in mg/100 g of soil

Depth, cm	Method of extraction							
	Kirsanov		Truog		Chirikov			
	Place samples were taken							
	Steppe	"D"forest	Steppe	"D"forest	Steppe	"D" forest	Steppe	Plowed
0—10	11	7	10	7	12	6	9	7
20—30	11	7	9	8	8	5	6	7
40—50	10	12	9	10	7	7	—	7
60—70	11	11	12	13	9	9	6	9
80—90	15	17	15	16	8	9	9	9
100—110	16	—	15	—	8	—	10	9

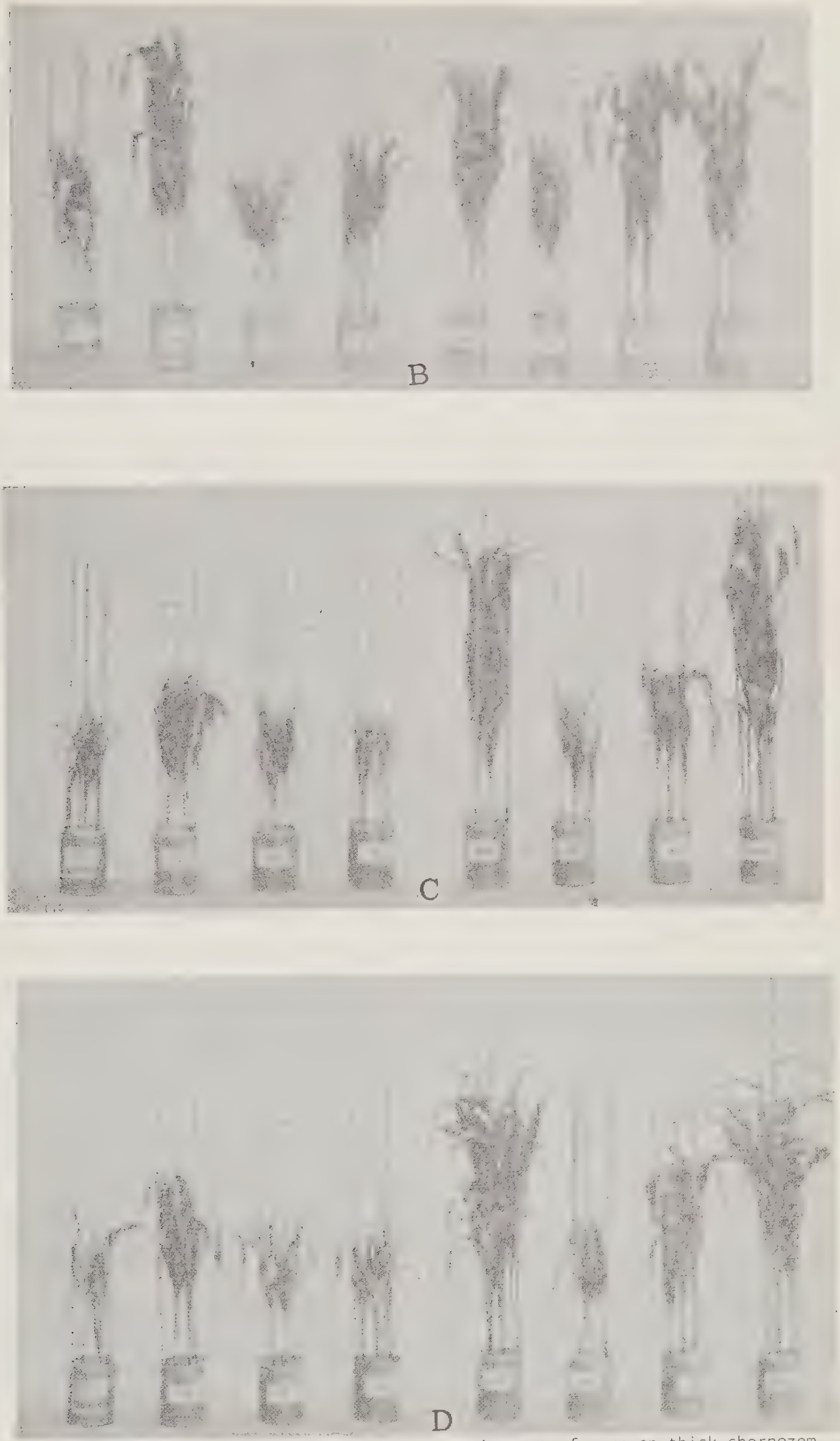

Fig. 1.- Influence of fertilizers on the development of corn on thick chernozem under various agricultural uses.

Soil: A - uncut steppe; B - "D" forest; C - plowland under cover; D - "P" forest.

surrounded by young oaks, blackthorn underbrush, false hellebore, bitter peavine, and bedstraw.

Tables 1-3 give certain data characterizing these soils.

The soil from the "D" forest in contrast to the soil from the uncut steppe, and the soil from the "P" forest in contrast to the plowed soil, are characterized by a higher nitrogen and humus content in the upper layers, while in the lower layers (from 20-30 cm to 80-90 cm) they are distinguished by a lower nitrogen and humus content (Table 1). The forest soils also have a higher exchangeable potassium content in the plowed layer than do the steppe and plowed soils.

The results of analyses of the content of total phosphorus and phosphorus soluble in weak acids in the soil are given in Tables 2 and 3. The results show that: 1) the total phosphorous content along the soil profile to a depth of about 1 m is higher in the forest soils than in the steppe and field soils, but the phosphates in them are less soluble in weakly acid extracts; and 2) the content of phosphorus soluble in weak acids increases with depth. This once more confirms the fact that the methods of determining available phosphates, developed for the plowed soil layers, are unsuitable for determining the forms of phosphorus available to plants along the soil profile; at a great depth those forms of phosphates enter into the solution which are unavailable to plants.[2] (See next page for footnote).

Table 4

Influence of fertilizers on plant development on thick chernozem under various uses. Results of pot experiments, per pot

Experimental setup	Crop	Place soils were taken			
		Steppe	"D" forest	"P" forest	Plowed
Without fertilizers	Corn	6,4	16,7	7,7	7,4
Addition of N		11,3	40,8	16,5	14,6
" P		9,0	18,9	10,5	10,4
" K		7,1	17,7	9,5	8,8
" NP		53,5	69,2	61,0	50,9
" PK		9,4	17,0	9,5	10,6
" NK		10,7	39,2	17,1	16,0
" NPK		61,3	71,0	64,8	71,2
± m_M		2,1	1,3	2,6	0,9
Without fertilizers	Spring wheat	6,9[a] / 2,2	15,8 / 5,9	9,3 / 3,4	7,5 / 2,3
Addition of NP		23,5 / 7,9	32,1 / 9,6	27,5 / 7,9	16,3 / 4,2
" PK		12,3 / 3,6	18,4 / 6,2	14,2 / 4,7	11,0 / 3,2
" NK		8,3 / 2,0	21,8 / 7,8	12,4 / 4,4	9,8 / 3,1
" NPK		35,7 / 10,5	38,0 / 11,5	36,1 / 11,6	30,9 / 8,9
± m_M		0,46 / 0,67	1,0 / 0,65	0,62 / 0,39	0,33 / 0,16

---

[a] The numerator gives the total weight of dry spring wheat; the denominator gives the weight of grain.

Note: comma denotes decimal point.

Table 5

Influence of individual nutrients on plant development on thick chernozems. The data are in relative values[a]

Increments due to fertilizers	Experimental crop	Place soils were taken			
		Steppe	"D" forest	"P" forest	Plowed
N against a backgr. of PK	Corn	552	318	582	571
" "	Spring wheat	190	85	146	178
P against a backgr. of NK	Corn	473	81	280	345
" "	Spring wheat	425	47	170	190
K against a backgr. of NP	Corn	14	2	6	43
" "	Spring wheat	33	20	52	112

[a] The weight of corn plants or the weight of wheat grains obtained against the corresponding background is taken as 100.

Table 6

Phosphorous content and accumulation in plants on thick chernozem under various uses. The results of pot experiments are in percent of dry matter, mg per pot

Place where samples were taken	Corn		Spring wheat		
	P_2O_5		P_2O_5 в %		
	in %	in mg per pot	grain	straw	P_2O_5 in the grain and straw, mg per pot
Steppe	0,19	12	0,83	0,14	24
"D" forest	0,42	70	1,15	0,20	89
"P" forest	0,27	21	0,99	0,16	43
Plowed	0,23	17	1,06	0,17	33

Note: comma denotes decimal point.

The foregoing fact of the increase of the total phosphorus, nitrogen, and humus content in the soil also has been observed by Akhtyrtsev (2) in oak plantations (80 years old) in the area of Shipov forest. On the basis of data in Table 3 one could have assumed that the forest soil is poorer in phosphates available to plants and that the additional application of phosphorus with the fertilizers would give a greater effect than on steppe and plowland soil. Such an assumption could have been verified only by pot experiments. In order to do this we made 2 pot experiments on samples taken from the plowed layer of the soils described earlier.

When the pot experiments were started, the moisture of the soil from the clover field was 17%, while that of the remaining 3 soils was about 20% of the weight of the soil. Pots 15 x 20 cm in size and of a capacity of about 3.5 kg of soil were used in the experiment.

The fertilizers added were: N in the form of ammonium nitrate at a rate of 0.95 g per pot under corn and 0.4 g under spring wheat; K_2O in the form of potassium sulfate at a rate of 0.4 g per pot under corn and 0.5 g under spring wheat; and P_2O_5 in the form of monocalcium phosphate at a rate of 0.75 g per pot under corn and 0.75 g under spring wheat.

The spring wheat was sown on May 19 and harvested on August 23 when it was completely mature. The corn was sown on May 27 and harvested on August 15 when it was in the tasseling stage. Table 4 gives average data on the weight of the dried plants, and also the weight of the grain for spring wheat under all treatments. For the sake of convenience, Table 5 gives the relative weight increments of dry corn plants and the weight of spring wheat grain resulting from the application of individual plant nutrients against a background of two other fertilizer components.

The data show (Table 4) that the fertility of the thick chernozems in the Kursk Oblast', studied on soil samples taken from the Kursk reservation and the adjoining solkhoz, is

---

[2] The reduction of the availability of phosphates from the deeper soil layers to plants as compared to the plowed layer was demonstrated by Ganzha (5), and Kheyfets (7).

Table 7

Amount of phosphorus in the uncut steppe and forest soils

Place where samples were taken	P_2O_5 in metric tons ha in the upper 1 m of soil		
	total	organic	inorganic
		compounds	
Uncut steppe	13.1	7.0	6.1
"D" forest	16.3	6.8	9.5

characterized by somewhat different indices when different plant communities develop on these soils.

Thus both corn and spring wheat developed almost two and one-half times better on the soil from the "D" forest without fertilizers than on the soil of the uncut steppe. On the soil from the "P" forest, as well as on the plowed soil from the Petrin sovkhoz, the plants developed without fertilizers almost in the same way as on the soil of the uncut steppe.

On all 4 soils corn developed as weakly without the addition of nitrogen fertilizers (when PK was applied, see Table 4) as it did on nonfertilized soils, while spring wheat did show an increment in yield, but this increment was insignificant as is usually the case in pot experiments. It must be noted that the yield increments of both crops from nitrogen fertilizers were almost two times smaller on the soil from the "D" forest than on the other soils, which points to the higher content of available nitrogen in this soil as compared to the other three.

The addition of nitrogen fertilizers only resulted in a considerable increase in the vegetable mass of corn on the same soil from the "D" forest, while on the three remaining soils it was necessary to apply nitrogen and phosphorous fertilizers simultaneously in order for the plants to develop normally (Table 4). This fact, together with the considerably smaller yield increment from the application of phosphates on this soil, as compared to the yield increments of both crops on the remaining soils (for increments from "P", see Table 5), indicates that the first soil has a considerably larger content of available forms of phosphates than do the other three soils, which clearly show a deficiency in available phosphates. Forest vegetation apparently promotes the transformation of soil phosphorus into more readily available forms, as was mentioned by Akhtyrtsev (2).

N. I. Bolotina (3) concluded, on the basis of field experiments made by her on the same uncut steppe, that the soil had the necessary supply of phosphates for a crop of herbaceous vegetation. The differences in the results can be explained for the most part by the different phosphorous requirements of grain and herbaceous plants; moreover a complete biological phosphorous cycle takes place in field experiments in the uncut steppe and it is difficult to expect a reaction of steppe vegetation to phosphates. The greater availability of phosphates in forest soils as compared to steppe and plowed soils in the area of the Kursk reservation was also noted by Kolgopolova (6) on the basis of pot experiments and by Verigina (4) on the basis of analytical investigations.

The application of potassium fertilizers against a background of nitrogen and phosphorous fertilizers produced a considerable effect only in the plowed soil of the Petrin sovkhoz (Tables 4 and 5), which is associated with the long-term use of this soil (old plowed farmers' land) without fertilizers.

It must be noted that the effectiveness of fertilizers on the soils studied was about the same both in the experiment with corn and in the experiment with spring wheat (Tables 4 and 5). Figure 1 illustrates well the quantitative data obtained in the experiment with corn.

To verify the assumption made on the basis of yield data on the differential supply of available phosphates in the soils under various agricultural uses, corn plants as well as the spring wheat grain and straw (from fertilized pots) were analyzed for their content in phosphorus (Table 6).

The results of the analysis (Table 6) as well as the yield data point to the considerably greater uptake of phosphorus by plants from the soil in the "D" forest than from the steppe soil (these soils are close to each other) and to the same tendency with respect to plants developing on the second soil from the "P" forest as compared to the plants in the experiment on plowed soil.

The data (Table 7) for the contents of total phosphorus as well as the phosphorus of organic and inorganic compounds in the upper 1 m of the soil and their comparison with the data on the development of plants on the same soils (Table 4) confirm the existing opinion that plants utilize first the phosphates from inorganic soil compounds and not those of organic compounds, the content of which is the same in the two soils compared.

Conclusions

1. The thick chernozems of the area of the Kursk reservation differ in their content of available phosphorus and potassium and, consequently, also in the effectiveness of the fertilizers applied.

2. The soils best supplied in nutrients proved to be the forest soils because of their higher content of total phosphorus and potassium as well as their forms available to plants, as may be judged by the reaction of plants developing on them to the fertilizers applied.

3. Similar soil (thick chernozem) from an uncut steppe, located a short distance from soil of the "D" forest, is considerably less supplied with phosphorus (and potassium) than the first soil and, consequently, may require phosphorous fertilizers after it is plowed for the normal development of agricultural plants on it.

4. The considerable deficiency of potassium in the plowed soil, which has been noted in the experiments and which is not characteristic for

thick chernozems, apparently is due to the long-term use of this soil (old plowed farmers' land) under sugar beet without the application of fertilizers.

Received February 9, 1960

BIBLIOGRAPHY

1. AFANAS'YEVA, YE. A. 1947. Origin, composition, and properties of the thick chernozems of Streletskaya steppe. Trudy Pochvennogo Instituta im. V. V. Dokuchayeva Akad. Nauk SSSR. Vol. 25.
2. AKHTYRTSEV, B. P. 1956. Change of ordinary chernozem under the influence of an 80-year old oak plantation. Pochvovedeniye, No. 11.
3. BOLOTINA, N. I. 1950. Nitrogen regime in virgin steppe soils. Trudy Pochvennogo Instituta im. V. V. Dokuchayeva Akad. Nauk SSSR. Vol. 33.
4. VERIGINA, K. V. 1948. Content, availability, and forms of phosphorus compounds in the chernozems of the Streletskaya steppe. Trudy Tsentral'nogo chernozemnogo zapovednika, No. 11.
5. GANZHA, B. A. 1938. Profile study of the fertility of podzolic soils. Trudy Pochvennogo Instituta im. V. V. Dokuchayeva Akad. Nauk SSSR. Vol. 17.
6. DOLGOPOLOVA, N. N. 1948. Physical and agricultural-chemical characterization of soils with a forest-steppe profile under conditions of the Central Chernozem Reservation. Trudy Tsentral'nogo chernozemnogo zapovednika, No. 11.
7. KHEYFETS, D. M. 1952. Problem of the nutritional regime of the terrace soils of the Kutuluk irrigated area. Trudy Pochvennogo Instituta im. V. V. Dokuchayeva Akad. Nauk SSSR. Vol. 37.

CHARACTERISTICS OF THE AGGREGATION OF SOILS IN THE SOUTHEAST

A. I. SKREPINSKIY, Saratov Agricultural Institute

The problem of the structure formation of soils is a basic one in agriculture; it is closely related to the means of increasing the fertility of soils.

In the opinion of V. R. Vil'yams, the formation of soil aggregates during the meadow stage of soil development takes place under the influence of the roots of perennial grasses. Observations show that the root systems of perennial grasses have their characteristic distribution in the soil. Proceeding from this, we hoped to determine to what degree the characteristic distribution of perennial grass roots affects the nature of the formation of water-stable aggregates. We proposed to establish the best structure formers for the irrigated dark-chestnut soils of the Southeast. Experimental sowings of mixed grasses consisting of perennial grasses on an irrigated plot of dark-chestnut clay loam soils were used. Experiments took place at the Saratov Agricultural Institute's uchkhoz, located near the city of Engels. The grass yields from these sowings, when irrigated twice, varied from year to year from 60-80 centner of hay in two cuttings per hectare.

The soil samples were taken in September-October from a depth of 0-20 cm; the neighboring plots without grasses served as controls. The samples were analyzed in an air-dry state. The content of stable aggregates was determined by the Savvinova method, according to the procedure used at the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR.

The investigations did not give the expected results: there was no difference in the composition of aggregates in soil samples taken from under various grasses. On the contrary, the aggregates were characteristically similar and of a small size. An increase in the number of aggregates always occurred at the expense of small fractions (2-0.5 mm in diameter). In order to determine whether this tendency remains the same under different conditions, we analyzed samples taken at other points in an old (18 years) Agropyron stand in a dry-farming area of the same uchkhoz. We used as controls samples taken from a neighboring barley sowing on old plowland. In addition, samples from under a 4-year old brome grass stand and spring wheat on old plowland in the Krasavskiy sovkhoz, Krasavskiy rayon, were also analyzed. The soil was an ordinary clay loam chernozem.

The results of the analyses are presented in Table 1. The degree of aggregation was calculated from the difference between the number of aggregates in the abandoned land and in the old plowland.

Table 1 shows that large fractions (>3 mm in diameter) do not participate in aggregation, or participate to an insignificant degree. An even lesser role is played by medium fractions (3-2 mm in diameter). In contrast to this, small fractions (2-0.5 mm in diameter) play an essential role in structure formation; at the same time the number of the smallest aggregates (0.5-0.25 mm in diameter) usually decreases as aggregation increases. This pattern is followed both in pure sowings and in mixed grasses, under irrigation and in dry-farming areas, and in dark-chestnut soils and in chernozems.

A similar aggregation process is also observed in other regions of Saratov Oblast'. In order to give a more complete picture of the dynamics of this process, Table 2 includes the summarized results of aggregate analyses for the dark-chestnut soil of the irrigated plot with 3-year old smooth brome grass in the uchkhoz of the Saratov Agricultural Institute.

It can be seen from Table 2 that the dynamics of aggregation of dark-chestnut soil under the influence of the root system of smooth brome grass follows the same pattern as shown by data in Table 1: the number of stable aggregated soils increases from year to year primarily in the fractions 2-0.5 mm in diameter. The same picture is observed under meadow fescue.

This type of aggregation does not agree with the views of V. R. Vil'yams on the role of perennial grasses in the formation of stable aggregates. Therefore we decided to compare the results of our investigations with similar data obtained in another zone. We used the material collected in 1933 by the brigade of the Moscow soil-research station under the leadership of V. R. Vil'yams (8). The tasks of the brigade included the determination of the effect of perennial grasses on the structure of the typical soil varieties in Moscow Oblast'. Fields with perennial grasses (primarily clover with timothy) were selected in various farms; old plowlands were used as controls. The method of analysis was similar to ours. Table 3 gives

Table 1

Nature of the aggregation of soils in Saratov Oblast'

Sample	Number of aggregates, % of air-dry sample					Aggregation, %	Increment of aggregates, % of total aggregation			
	Aggregate diameters, mm						Aggregate diameters, mm			
	> 3	3—2	2—0,5	0,5—0,25	Total		> 3	3—2	2—0,5	0,5—0,25
Uchkhoz of the Agricultural Institute. Dark-chestnut soil under irrigation										
Alfalfa-Agropyron 1953-1955	0,3	0,3	26,5	24,9	52,0	3,7	5	—8[a]	76	27
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Alfalfa-fescue, 1953-1955	0,3	0,7	38,1	20,9	60,0	11,7	2	1	123	—26[a]
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Alfalfa-brome grass, 1953-1955	1,0	1,6	34,5	16,8	53,9	5,6	16	18	193	—127
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Sainfoin-brome grass, 1953-1955	2,2	1,7	32,6	17,9	54,4	6,1	34	18	146	—98
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Sainfoin-fescue, 1953-1955	0,4	0,7	30,8	23,6	55,5	7,2	4	1	99	—4
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Fescue, 1951-1955	0,6	1,2	37,1	17,1	56,0	7,7	6	8	174	—88
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Brome grass, 1951-1955	2,8	3,0	42,6	14,4	62,8	14,5	19	16	130	—65
Old plowland, 1955	0,1	0,6	23,7	23,9	48,3					
Alfalfa-brome grass, 1953-1956	0,1	0,3	31,2	23,7	55,3	6,2	0	1	131	—32
Old plowland, 1955	0,1	0,2	23,1	25,7	49,1					
Alfalfa-Agropyron, 1953-1956	0,1	0,4	30,1	22,9	53,5	4,4	0	5	159	—64
Old plowland, 1955	0,1	0,2	23,1	25,7	49,1					
Average under irrigation							9,5	6,6	136,8	—52,9
Uchkhoz of the Agricultural Institute. Dark-chestnut soil in dry-farming area										
Agropyron, 1938-1956	1,9	1,5	26,7	13,0	43,1	16,5	10,9	7,3	101,8	—20,0
Rye on old plowland, 1956	0,1	0,3	9,9	16,3	26,6					
Krasavskiy sovkhoz. Ordinary chernozem										
Brome grass, 1951-1954	1,6	1,7	39,5	16,2	59,0	5,1	21,6	13,7	172,5	—107,8
Spring wheat on old plowland, 1954	0,5	1,0	30,7	21,7	53,9					
Average							14,0	9,2	137,0	—60,2

---

[a] The minus sign indicates a decrease in the amount of the fraction.

Note: Comma represents decimal point.

Table 2

Change in the soil structure under smooth brome grass (amount of water-stable aggregates, in % of sample)

Years in use	Aggregate diameters, mm				Total
	> 3	3–2	2—0.5	0.5—0.25	
Second	0,2	0,3	24,5	19,2	44,2
Third	1,5	1,8	39,0	17,1	59,4
Fourth	2,8	3,0	42,6	14,4	62,8

Note: Comma represents decimal point.

Table 3

Nature of the aggregation of soils in Moscow Oblast'

Sample	Number of aggregates, % of air-dry sample					Aggregation, %	Increment of aggregates, % of total aggregation			
	Aggregate diameter, mm						Aggregate diameter, mm			
	> 3	3—2	2—0,5	0,5— —0,25	Total		> 3	3—2	2—0,5	0,5 —0,25
Sod-podzolic soil										
3-year old grasses	19,9	2,8	25,3	11,0	59,0	22,5	65,3	7,1	47,9	—20,3
Old plowland	5,2	1,2	14,5	15,6	36,5					
Gray forest soils										
3-year old grasses	27,9	4,7	11,8	8,8	53,2	31,7	67,2	8,5	22,1	2,2
Old plowland	6,6	2,0	4,8	8,1	21,5					
Thick chernozem										
Abandoned land	45,0	7,6	24,4	6,1	83,1	25,5	140,0	11,4	—31,8	—19,6
Old plowland	9,3	4,7	32,5	11,1	57,6					
Average							90,8	9,0	12,8	—12,6

Note: Comma represents decimal point.

selected data from this material, arranged in the same order as in Table 1.

Table 3 shows that the aggregation of soils in Moscow Oblast' has a different character: a leading role in aggregation is played by large fractions (>3 mm in diameter), while small fractions (2-0.5 mm in diameter) play a less important role in this process. The content of the smallest fraction (0.5-0.25 mm in diameter) decreases as aggregation proceeds, but not to such a degree as in the soils of Saratov Oblast', and medium-size fractions (3-2 mm in diameter) participate little in aggregation.

To be able to compare the difference in the nature of aggregation in the Saratov and Moscow Oblast', Table 4 gives the average indices of the participation of fractions of various diameters in aggregation, in conformity with Tables 1 and 2.

Table 4 shows that in the steppe zone of the Southeast, aggregation takes place primarily in small fractions (2-0.5 mm in diameter), while in the forest-meadow zone it takes place in the large fractions (>3 mm in diameter). In both zones medium-sized fractions (3-2 mm in diameter) participate little in aggregation.

The foregoing data lead to the conclusion that there are three types of biological aggregation in nature: the root, rhizospheric, and intestinal (author's terminology).

In the root type of aggregation the plant roots take a direct part in aggregate formation. During their growth they compress the soil particles into small blocks > 3 mm in diameter, which then become cemented as a result of the activity of microorganisms developing at the expense of dying roots. This type of aggregation has been fully described by Kostychev and Vil'yams (2, 4).

As Kostychev writes, parts of the sod layer

Table 4

Nature of aggregation according to zones (increment of aggregates, in % of total aggregation)

Zone	Aggregate diameter, mm				
	> 3	3—2	2—0,5	0,5—0,25	Total
Southeast steppe	14	9	137	—60	100
Forest-meadow	91	9	13	—13	100

Note: Comma represents decimal point.

"consist only of small aggregates usually of a size varying from that of a lentil to that of large peas." Here he stresses the large size of the aggregates which form in abandoned land.

V. R. Vil'yams describes the process of aggregation thus: "As loosely bunch grasses develop, their roots develop more and more frequently along small old root channels... The pressure on the walls of the channel, which is created by the thickening roots during their growth, increases as new roots develop, since the channels become inevitably more and more filled with dead organic residue. Finally, the soil between the roots reaches its maximum compaction and the whole mass of the soil begins to crack under the smallest pressure along surfaces of least resistance, the location of which is determined by the endless number of intersecting root channels."

The rhizospheric type of aggregation takes place in the rhizosphere as a result of microbiological processes taking place in it. Small aggregates (2-0.5 mm in diameter) form during such aggregation.

The great importance of the rhizosphere in aggregation was noted by Mushustin (6). On the basis of his own investigations he concludes that "... root residues play a noticeably smaller role in structure formation than do live roots and the microflora surrounding them."

Gel'tser (3) came to similar conclusions as a result of her lysimeter experiments. She maintains that a large part of active humus in the soil is accumulated by rhizospheric bacteria during the life of perennial grasses.

During aggregation of the intestinal type, aggregates form in the intestinal tract of certain burrowing animals. This type of aggregation is described by Darwin in his classical work on earthworms (4). Such aggregation may be observed in the piedmont areas of the Caucasus, in the vicinity of Kislovodsk. There the soils of mountain meadows, which have an ideal structure, are densely riddled by the passages of earthworms. Observations in recent years show that the coprolite of earthworms is very stable and is sometimes found in great amounts in the forest-meadow zone.

All three types of aggregation take place simultaneously, but one or the other type predominates, depending on the combination of soil formation factors in individual regions. This leaves an impression on the form and size of the aggregates, in particular in the southeastern steppe and forest-meadow zones.

The question arises: why do large aggregates (>3 mm in diameter) form during the root type of aggregation and small aggregates (2-0.5 mm in diameter) during the rhizospheric type of aggregation, while the number of medium-sized aggregates (3-2 mm in diameter) does not change?

During the root type of aggregation, the size of the aggregates is determined by root passages. Consequently, the distance between the roots (we call it conditionally the "root network") must determine the size of the aggregates: the more dense this network, the finer the aggregates will be.

During rhizospheric aggregation the aggregates are not being compacted by the roots. They form in the rhizosphere and therefore their size must somehow reflect the diameter of the zone of propagation of root hairs.

Proceeding from these assumptions, we conducted investigations in this direction. We measured the interstices of the root networks of certain plants. The size of the interstices was determined by the distance between neighboring roots on herbarium material. The values obtained were doubled under the assumption that two neighboring roots in the soil usually separate in different directions. Table 5 gives the results of such measurements.

Table 5

Characteristics of the root network, % amount of spaces by fractions

Crop	Space size, mm			
	> 3	3—2	2—1	< 1
Agropyron #1	77	23	0	0
" " 2	83	17	0	0
Brome grass "2	69	27	4	0

The data in Table 5 show that the majority of the interstices were >3 mm; there were no interstices of < 1 mm. Consequently, the root networks of the plants could only form aggregates > 2-3 mm in diameter, since the soil in this case fissured along the root tubes.

The results of measurements of the rhizosphere of certain perennial grasses are presented in Table 6, which shows that the diameter of the zones of the propagation of root hairs (rhizosphere) for various perennial grasses varies from 0.6-2.8 mm, and is generally 1.5-2 mm. With the rhizospheric type of aggregation, aggregates of this size must form.

An indirect confirmation of our correct conclusions on the presence in nature of a root and rhizospheric type of aggregation is the fact that aggregates 3-2 mm in diameter play an insignificant role in aggregation, both in the steppe and in the forest-meadow zones. If the increase in the quantity of aggregates during aggregation is represented graphically according to fractions in sod-podzolic soil (Fig. 1), then two peaks in the curve would be clearly seen: the quantity of aggregates >3 mm in diameter and from 2-0.5 mm in diameter increases, while the quantity of aggregates 3-2 mm in diameter does not change significantly. A "saddle" appears on the curve. This decrease is less noticeable in the soils of the Southeast because the large aggregates (> 3 mm in diameter) in this zone participate little in aggregation.

We attribute the small role played by medium-size aggregates (3-2 mm in diameter) in aggregation to the fact that they cannot form in the interstices of the root network, because they are too small, while for rhizospheric aggregation they are too large, larger than the diameter of the zone of propagation of root hairs.

Consequently, the preliminary investigations of root networks and rhizospheres of certain plants confirm the correctness of our assumption of the existence of three different types of aggregation in nature.

On the basis of the foregoing we conclude that the aggregation of soils under the influence of grass vegetation in the Southeast is achieved by rhizospheric aggregation. This process takes place in the propagation zone of root hairs during the life activity of the root system in the growing period. Therefore there should be no difference between soil aggregation under perennial grasses and annual crops in the Southeast.

This is actually confirmed by our investigations in the "Iskra Il'icha" kolkhoz on ordinary, medium clay loam chernozem in the Vol'sk rayon.

Soil samples taken from under winter rye, sown over soil deeply plowed without a moldboard, showed a considerable increase of stable aggregates during its growing season. This rye yielded 11.4 cntr/ha in 1956, as weighed in hoppers.

Table 7 shows the results of aggregate analysis at two periods: during the flowering stage, and in autumn after the stubble had been disced. It shows the content of stable aggregates in percent of air-dry sample according to fractions in the main root zone (15-20 cm).

It can be seen from Table 7 that aggregation under winter rye occurred in the small aggregates (2-0.5 mm in diameter). The quantity of large aggregates (>3 mm in diameter) did not change and generally there was very little of these aggregates. Consequently, in this case aggregation was also of the rhizospheric type, which was even more pronounced than under perennial grasses. This verifies our conclusion on the absence of a qualitative difference in the role of annual crops and perennial grasses in the aggregation of soils in the Southeast.

Table 6

Characteristics of the rhizosphere

Crop	Diameter of rhizosphere, mm	
	Average	Deviations
Brome grass No. 1	1,8	1,2—2,8
" " " 2	1,9	1,7—2,1
Creeping quack grs	2,2	1,7—2,8
Sainfoin	1,6	—1,8
Alfalfa	0,8	0,6—1,0

Note: Comma represents decimal point.

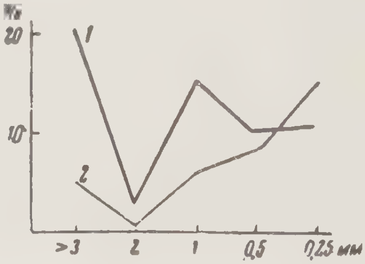

Fig. 1. - Nature of the aggregation of sod-podzolic soil from Moscow Oblast' (quantity of aggregates by fractions, %)
1 - abandoned land; 2 - old plowland.

Conclusions

1. There are three types of biological aggregation processes in soils: the root, rhizospheric, and intestinal types.

In the root type of aggregation, the roots take a direct part in the formation of aggregates > 3 mm in diameter.

The rhizospheric type of aggregation takes place in the rhizosphere, whereby aggregates 2-0.5 mm in diameter form.

In the intestinal type of aggregation the aggregates form in the intestinal tracts of certain burrowing animals.

Table 7

Nature of aggregation under winter rye, quantity of aggregates, %

Date	Fractions, mm					
	>3	3—2	2—1	1—0,5	0,5—0,25	Total
June, 1956	0,1	0,2	2,2	9,2	20,8	32,5
October, 1956	0,1	0,7	11,5	24,2	14,8	51,3
Increment	0,0	0,5	9,3	15,0	—6,0	18,8

Note: Comma represents decimal point.

All three types of aggregation take place simultaneously, but one of the types may predominate over the others, depending on the combination of soil-formation factors.

2. In the Southeast soil aggregates form primarily by rhizospheric aggregation, which leaves an impression on the time and rate of aggregation, and the shape and sizes of the forming aggregates.

3. With the rhizospheric type of aggregation there is no qualitative difference between perennial grasses and annual row crops as structure-forming agents. Therefore the soil in the Southeast can be aggregated both under fallow row-crop rotation and under a grass-arable system under proper agricultural practices.

Received February 9, 1959

BIBLIOGRAPHY

1. Agricultural-chemical methods of soil investigation. 2d ed. 1954. Akad. Nauk SSSR.
2. VIL'YAMS, V. R. 1936. Soil science. 3d ed.
3. GEL'TSER, F. YU. 1956. Grass formation and the soil formation process. Pochvovedeniye, No. 11.
4. DARWIN, C. 1936. Formation of the vegetative soil layer from the activity of earthworms and observations on their way of life. Collected works. Vol. 2.
5. KOSTYCHEV, P. A. 1951. Selected works. Outlines of abandoned land farming. Izd. Akad. Nauk SSSR.
6. MISHUSTIN, YE. N. 1956. Microorganisms and fertile soils. Izd. Akad. Nauk SSSR.
7. RUSSELL, E. 1955. Soil conditions and plant growth. 4d ed.
8. ROSTOVTSEVA, O. S. and M. N. AVAYEVA. 1935. Role of perennial grasses in the formation of soil structure. Pochvovedeniye, No. 5-6.

WATER REGIME OF ORDINARY CHERNOZEMS IN THE KAMENNAYA STEPPE

I. P. SUKHAREV, Kursk Agricultural Institute

The water regime of the soil in the steppe zone of the southeastern part of the Central Chernozem Belt is rather unusual. Crop yields vary sharply from year to year depending on the moisture content of the soil in spring and the amount of atmospheric precipitation during the growing period. Droughts are very frequent and greatly reduce the yield of agricultural crops. In the last 15 years the drought years were: 1946, 1954, 1957, and 1959. The water regime of the soil in spring and during the entire growing period is favorable in individual years. In the last 10 years such years were: 1949, 1952, 1955, and 1958. Let us describe the characteristics of the water regime of ordinary chernozem in the Kammenaya Steppe (southeast, Voronezh Oblast') according to our investigations made in the fields of the Dokuchayev Agricultural Institute of the Central Chernozem Belt from 1949-1958, using the data on soil moisture collected by the meteorological station of the Kamennaya Steppe and those given in the works of Burnatskiy and Suchalkina (5, 6).

The soil in the area where moisture observations were made is rather uniform and is represented by ordinary chernozem having a humus horizon 0.5-0.6 m thick.[1] The field moisture capacity of the upper 1 m of the soil is 370 mm, and the content of bound moisture (wilting moisture) is 134 mm.

Seasonal Fluctuations of Soil Moisture

Soil moisture is in constant motion under the influence of capillary and gravitational forces, of the temperature of various soil layers and of the air at the soil surface (8, 16, 20). The recharge of soil moisture occurs in the autumn and winter from rains and during snow melting in spring. Moisture is lost from the soil during the period of the intense development and water consumption of agricultural crops in May, June, July, and August.

P. A. Kostychev (13) mentioned the great role played by autumn precipitation in the formation of the water regime of the soil: he wrote "...a year for the chernozem region may be divided in two halves; during one half the chernozem accumulates moisture and during the other half it gradually dries out." Under the conditions of the southeastern part of the Central Chernozem Belt the first period begins in September and ends in April of the following year. From May to July-August soil moisture is being lost intensely. Figure 1 shows curves of the change in the moisture content of the upper 1 m of soil in fields under spring and winter wheat located in the steppe, and also in a fallow field during the hydrological year from October to September of the following year. These curves were constructed on the basis of average data for 14 years (1944-1957).

Figure 1 shows that the amount of soil moisture increases considerably from December to January. It is small in January-February and increases sharply again during the snow-melting period in spring. The largest moisture content in spring and winter wheat fields is observed in April; during the following months (May, June, and July) it is lost intensely from plant transpiration and evaporation from the soil surface. In July the soil moisture in these fields reaches a minimum; then, beginning in August (after the harvest), the moisture content is being gradually restored.

Moisture accumulates in black fallow almost in the same way as it does under spring and winter wheat, but its consumption in May, June, and July is less than in fields under crops. There is on the average 70 mm more moisture in black fallow in August than in fields having been under agricultural crops.

The loss of soil moisture from April to July was 115 mm in the spring wheat field, 125 mm in the winter wheat field, and only 60 mm in black fallow (Fig. 1). The average amount of precipitation from April to July, inclusively, in the Kamennaya Steppe is 180 mm. If this amount is added to the soil moisture loss in the period from April to July, the non-productive moisture loss from the black fallow field will be 240 mm. There is a considerable moisture deficit in the upper 1 m of soil, reaching 50-55 mm at the beginning of the growing period and 170-180 mm at the end of this period. To decrease the soil moisture deficit in the southeastern part of the chernozem zone requires agricultural, meliorative,

---

[1] A detailed description of the soil in Kamennaya Steppe is given in the works of Antipov-Karatayev and Kader (3) and Nikanorova (14).

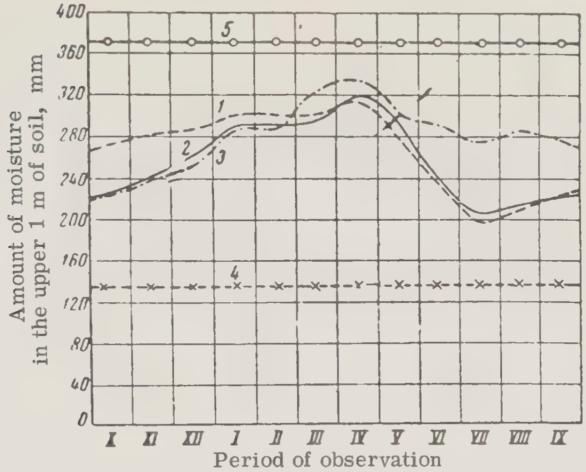

Fig. 1.- Change in the total amount of moisture in the upper 1 m of soil.

1 - winter wheat field; 2 - spring wheat field; 3 - black fallow; 4 - wilting moisture; 5 - field moisture capacity.

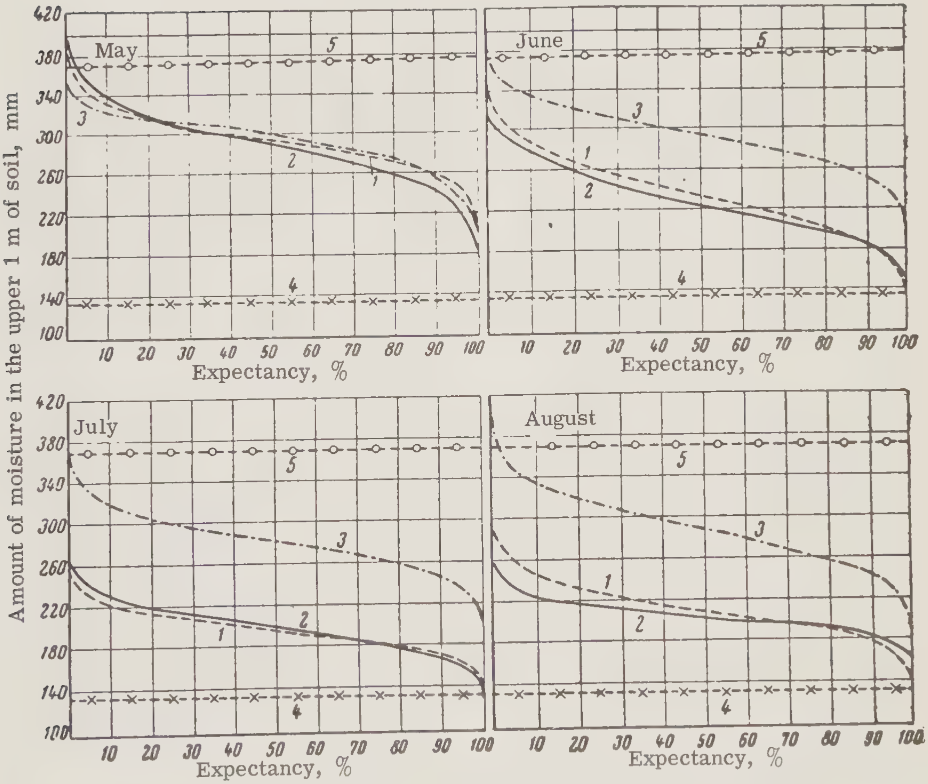

Fig. 2. - Curves of the change in the total amount of moisture in the upper 1 m of soil.

and silvicultural measures for the regulation of meltwater runoff.

Long-Period Fluctuations of Soil Moisture During the Growing Period (May-August)

As long-period observations, made in one and the same periods, show, soil moisture varies greatly.

Figure 2 gives the curves of the total moisture content in the upper 1 m of the soil in May, June, July, and August under winter and spring wheat and in the fallow of steppe field rotation. In 50% of the cases the soil moisture in May (mid-month) was 80% of the field moisture capacity, or slightly more. Only in certain years (3%-5% of the years) was the moisture content in May equal to the field moisture capacity of the soil. At expectancy of 90%-95% the amount of moisture in the soil is approximately equal to 60% of the field moisture capacity.[2]

The amount of soil moisture under winter and spring wheat continues to decrease considerably in June. The average amounts of moisture in June are only 10-15 mm higher than those corresponding to 60% of the field moisture capacity of the soil. Only rarely (5% of the years) does the moisture content in July correspond to 80% of the field moisture capacity. In approximately half of the years of observation the moisture content in the upper 1 m of the soil was less than 60% of the field moisture capacity in mid-June. The moisture content in the fallow was considerably higher than under winter and spring wheat in all periods of observation. The decrease in the amount of moisture in the fallow in July is insignificant as compared to June, while under winter and spring wheat the decrease is very sharp.

The amounts of moisture under winter and spring wheat in July fluctuate around 220 mm and equal 60% of the field moisture capacity in 20% of the cases. As can be seen from Figure 2, the amounts of moisture are lower than the foregoing in 80% of the years of observation. July is the last month of the growing period of grain crops, since the harvest begins in the second half of the month. The amount of soil moisture at this period is at a minimum. Soil moisture increases somewhat in August. In August the amount of moisture in the fallow was 290 mm and more in 50% of the years of observation. There are very few years in which the moisture content in black fallow is low in August in the southeast (Central Chernozem Belt) and insufficient for seedlings of winter crops to develop. Such a year was the drought year of 1957 when the moisture content in black fallow dropped sharply in August and interfered with autumn sowing.

Moisture Accumulation in Soil in the Autumn-Winter Period

Moisture begins to accumulate in the soil after the harvest of crops (autumn) and also in winter and during the snow-melting period in spring. The soil often receives the largest amount of moisture during the autumn period. Such months in the southeastern part of the Central Chernozem Belt are October, November, and partly December. This period is the most favorable for the restoration of soil moisture.

Table 1 gives representative data for 1948-1955 on the accumulation of moisture in the soil during the autumn and winter-spring periods in fields under various crops. This table shows that soil moisture increases rather considerably in all fields in autumn, i. e., from the end of the harvest to the beginning of winter (establishment of a permanent snow cover). In the 8 years of observation the increase in moisture in autumn in the soil layer from 0-150 cm averaged 64 mm. In winter the increase in soil moisture occurs during warm spells, which are rather frequent in the southeast. The recharge of soil moisture is considerably smaller during the snow-melting period in spring than in autumn. In the 8 years of observation the increase in moisture in spring in the soil layer from 0-150 cm averaged only 30 mm, or 47.0% of the increase in autumn. During the autumn-winter and spring periods the amount of moisture in the soil layer from 0-150 cm increased by 94 mm, 68% of which occurred in autumn.

Since winter precipitation contributes little to the recharge of soil moisture, the amount of moisture in the soil can be increased considerably by runoff regulation (retention of meltwater in the fields).

Absorption of Autumn and Winter Precipitation

The absorption of autumn-winter precipitation depends on its amount (rain and water content in the snow), residual moisture in the soil, its initial moisture, soil cultivation, etc. Below we give the results of calculations of the coefficient of autumn and winter precipitation absorption in various fields of the Kamennaya Steppe for a number of years of observation.[3]

It must be noted that, when calculating the coefficient of autumn and winter precipitation absorption, all types of precipitation falling during this period in the form of rain and snow must be taken into account. If in summer, precipitation of <5 mm is little effective, in autumn even a fine rain promotes the gradual increase in soil moisture in the absence of evaporation from the soil surface. Autumn and winter precipitation occurs primarily in the form of fine rain and snow. Thus, for instance, from 1948-1957 autumn precipitation of <5 mm comprised on the average 51% of the total precipitation for these years, while winter-spring precipitation (from December to March of the following year) amounted to 59.3%. Therefore, in determining the coefficient of absorption for autumn-winter precipitation we took into account the total sum of precipitation in the foregoing period (Table 2). In these calculations we included the months from September to December in the autumn-winter period. A permanent snow cover

---

[2] The total amounts of moisture in the upper 1 m, corresponding to 60% and 80% of field moisture capacity, are 220 mm and 295 mm, respectively.

[3] The coefficient of precipitation absorption by the soil is calculated, according to A.V. Protserov, as the ratio between the amount of precipitation moisture taken in by the soil and the sum of effective precipitation (more than 5 mm) in mm.

Table 1

Moisture accumulation in the soil (in the layer from 0-150 cm) under field rotation in the steppe in autumn and winter-spring periods, mm

Crop	Field No.	Autumn			Winter-spring period of the following year			Total moist. incre. during autumn and winter-spr. pr.
		Amt. moisture		Moisture incre-ment in autumn	Amt. of moist. aft. snow melting	Incr. of mois-ture in winter	Moisture contents in the snow	
		After the harvest	Before bgng. of winter					
1948								
Fallow	2	358,0	463,0	105	479,7	16,7	69	120,0
Sunflower	4	322,8	487,1	164,3	505,5	18,4	—	182,7
Spring wheat	6	390,9	492,6	101,7	559,1	66,5	—	168,2
Grasses	7	396,5	488,0	91,5	577,5	89,5	90	181,0
Average		367,0	483,0	116,0	530,0	48,0		164,0
1949								
Fallow	2	418,8	480,0	61,2	513,6	33,6	49	94,8
Sunflower	3	331,7	410,9	79,2	435,9	25,0	—	104,0
Spring wheat	6	338,9	419,2	80,3	467,2	28,0	—	108,3
Grasses	7	360,0	403,6	43,6	433,3	29,7	—	73,3
Average		363,0	429,3	66,3	461,0	29,0	—	95,8
1950								
Grasses	3	331,1	371,8	40,7	413,7	41,9	55	82,6
1951								
Grasses	3	312,7	418,8	105,6	470,8	52,6	60	158,3
Spring wheat	4	324,8	418,8	94,0	450,8	32.0	60	126,2
Average		319,0	418,8	99,8	458,0	42,5		142,0
1952								
Sunflower after spring wheat	4	357,0	387,0	30,0	438,0	51,0	—	81,0
1953								
Oats	4	388,0	426,0	38,0	450,0	24,0	—	62,0
1954								
Barley	1	283,2	298,4	15,2	306,0	7,6	30	23,2
Oats	3	259,3	298,9	39,6	327,2	28,3	—	67,9
Fallow	4	332,6	363,0	30,4	373,9	10,9	—	41,3
Winter wheat	5	317,8	380,3	62,5	405,0	24,7	—	87,2
Millet	6	267,3	337,0	60,7	376,7	39,7	—	100,4
Spring wheat	7	309,2	333,1	23,9	344,5	11,4	—	35,1
Average		287,0	336,0	49,0	356,5	20,5	—	59,5
1955								
Barley	1	283,2	298,4	15,2	301,8	3,4	45	18,4
Oats	3	259,3	298,9	39,6	327,2	28,3	—	67,9
Fallow	4	332,6	367,6	35,0	373,9	6,3	—	41,3
Winter wheat	5	267,0	329,0	62,0	359,3	30,3	—	92,3
Millet	6	276,3	337,0	60,7	376,7	39,7	—	101,4
Spring wheat	7	309,2	333,1	23,9	373,1	40,0	—	63,9
Average		288,0	329,0	39,4	352,0	24,6	—	64,0
Av. for 8 yrs.		324,0	388,0	64,0	418,0	30,0	—	94,0

Note: Comma represents decimal point.

Table 2

Absorption of autumn and winter-spring precipitation (in the layer from 0-150 cm) under steppe field rotation, mm

Crop	Autumn-winter (Sept - Dec)			Winter-spring (Jan - March) of following year			Autumn-winter and early spring periods (Sept-March)		
	Moisture increments	Effective precipitation	Coef. of prec. absorption	Moisture increments	Winter precipitation	Coef. of prec. absorption	Total moisture increments	Total precipitation	Coef. of prec. absorption
1948									
Fallow	104,0	245,5	0,43	16,7	69,0	0,24	120,7	324,5	0,37
Sunflower	164,3	245,5	0,67	18,4	60,0	0,31	182,7	305,5	0,60
Spring wheat	101,7	245,5	0,42	66,5	70,0	0,95	168.2	315,5	0,52
Grasses	91,5	245,5	0,38	89,5	92,0	0,97	181,0	337,5	0,54
Average	116,0	245,5	0,47	48,0	72,7	0,62	164,0	322,0	0,51
1949									
Fallow	61,3	96,6	0,64	33,5	50,0	0,67	94,8	146,6	0,65
Winter crops	79,2	96,6	0,82	25,0	50,0	0,50	104,0	146,6	0,95
Spring wheat	80,3	96,6	0,83	28,0	50,0	0,56	108,3	146,6	0,65
Sunflower	43,6	96,6	0,45	29,7	50,0	0,59	73,3	146,6	0,50
Average	66,3	96,6	0,69	29,0	50,0	0,58	95,8	146,6	0,650
1950									
Grasses	40,7	63,0	0,65	41,9	55,0	0,76	82,6	118,0	0,70
1951									
Grasses	105,6	139,0	0,75	52,6	60,0	0,86	158,2	199,0	0,80
Spring wheat	94,0	139,0	0,81	32,0	60,0	0,53	126,0	199,0	0,63
Average	100,0	139,0	0,72	42,5	60,0	0,71	142,5	199,0	0,71
1952									
Sunflower	30,0	69,2	0,44	51,0	60,0	0,85	81,0	129,2	0,62
1953									
Oats	38,0	165,0	0,23	24,0	80,0	0,30	62,0	245,6	0,25
1954									
Barley	15,2	74,1	0,21	8,0	25,0	0,32	23,2	99,1	0,23
Oats	39,6	74,1	0,53	28,3	32,0	0,89	67,9	103,1	0,59
Fallow	30,4	74,1	0,41	10,9	25,0	0,44	41,3	99,1	0,42
Winter wheat	62,5	74,1	0,84	24,7	30,0	0,82	87-2	104,1	0,83
Millet	60,7	74,1	0,82	39,7	42,0	0,95	100,4	116,1	0,86
Spring wheat	23,7	74,1	0,32	11,4	25,0	0,46	35,1	99,1	0,35
Average	49,0	74,1	0,52	20,5	30,0	0,68	59,5	104,0	0,57
1955									
Barley	15,2	152,4	0,10	3,4	35,0	0,10	18,4	187,4	0,10
Oats	39,6	152,4	0,26	28,3	45,0	0,64	67,9	197,4	0,33
Fallow	35,0	152,4	0,23	6,3	35,0	0,18	41,3	187,4	0,22
Winter wheat	62,0	152,4	0,40	30,3	45,0	0,67	92,3	197,4	0,46
Millet	60,7	152,4	0,40	39,7	45,0	0,87	100,4	197,4	0,54
Spring wheat	23,9	152,4	0,16	40,4	45,0	0,90	63 9	197.4	0 32
Average	39,4	152,4	0,26	24,6	41,6	0,59	64,0	184,0	0,35
Av. for 8 yrs.	64,0	134,0	0,48	30,0	49,5	0,60	94,0	183,5	0,51

Note: Comma represents decimal point.

does not form and frosts to not set in during the first half of December in the southeastern part of the Central Chernozem Belt. Precipitation during this period is mostly of the solid type. A permanent snow cover forms in the Kamennaya Steppe at the end of the second or the beginning of the third decade of December.

Snow usually accumulates during the winter-spring period (January, February, and March), and spring melting begins at the end of March. The snow disappears on the average by April 2-4.

Table 2 shows that the coefficient of absorption for autumn-winter precipitation (September-December) varies greatly from year to year. In individual years (humid and cold) it reaches 0.70 -8.80; and in years with a warm autumn (1953 and 1955) it drops to 0.23-0.25 as a result of increased evaporation from the soil surface. In 8 years (1948-1955) the coefficient of absorption for autumn-winter precipitation averaged 0.48.

In calculating the coefficient of absorption for winter-spring precipitation we used data on the water contents in snow obtained from snow surveys conducted in spring before snow melting. Table 2 shows that the coefficient of absorption for winter-spring precipitation is somewhat higher than that of autumn-winter precipitation. During the winter-spring period the absorption coefficient varied from 0.30 to 0.85 and averaged 0.60 in 8 years; during the autumn-winter period it varied from 0.11 to 0.84. The absolute value for the absorption of meltwater during the winter-spring period averaged 30 mm in 8 years, and during the autumn-winter period, 64 mm. Thus the soil accumulates the largest amount of moisture in autumn and in the first month of winter (September-December).

The total absorption coefficient for the autumn-winter and spring periods averaged 0.51 in 8 years, and varied annually from 0.25-0.80. The absolute value for the absorption of rain and meltwater in these periods varied from 62-163 mm, and averaged 94 mm in 8 years.

Utilization of Soil Moisture by Plants During the Growing Period

We mentioned earlier that the amount of moisture in the soil is at the maximum in spring after snow melting. As warm weather sets in moisture is lost in the transpiration of agricultural plants and evaporation from the soil surface. Soil moisture observations (12) show that grain crops consume almost all the available soil moisture by mid-summer.

The utilization of soil moisture by plants during the growing period and losses by evaporation from the soil surface during the same period are characterized by the coefficient of utilization of natural soil moisture contents (12).[4] Table 3 gives the coefficients of moisture utilization from the upper 1 m of the soil during the growing period of certain crops.

This table shows that the coefficient of soil moisture utilization varies considerably from year to year for all agricultural crops. It is highest during dry years and lowest in wet years. The coefficient of unproductive moisture losses in black fallow was on the average 3.2, 3.5, 3.7, and 3.1 times smaller than the coefficient of moisture utilization under winter and spring wheat, sunflower, and alfalfa, respectively.

Influence of Forests on the Soil Moisture Regime in Fields

Previously, we discussed the problems of the soil moisture regime in steppe fields. As we know, forests and forest belts in fields have a great influence on the increase in the moisture content in the soil because of the increased snow cover and the decrease in surface meltwater runoff. Many investigators, including Vysotskiy (7), Rode (16), Dolgov (9), Zonn (10, 11), Skachkov (18), Aleksandrov (7), Burnatskiy (6), and others, mentioned the great role that forest plantations play in the increase of the amount of soil moisture. Forest belts promote the accumulation of snow in the fields in winter. The soil under the thick snow cover in the forest belts is protected from deep freezing, its water permeability increases as a result, and a greater amount of meltwater during the snow melting period in spring is absorbed by the soil in fields surrounded by forest than in fields without forest (in the steppe).

Observations on soil moisture in the Kamennaya Steppe showed that in fields bordered by forest belts soil moisture was higher than in fields in the steppe. Soil in forested fields receives more moisture during the autumn-winter and spring periods than that in fields in the steppe. Table 4 shows the amounts of moisture in the upper 1 m of soil in forested fields and fields in the steppe after snow melting in spring from 1944-1958. In all years soil moisture was higher in spring in the field bordered by a forest belt than in the steppe. The largest difference between the amount of moisture in the soil of the forested field and of the steppe was 92.8 mm (1945), and the least was 12 mm (1953). In 15 years it averaged 47 mm.

Figure 3-A shows that the amount of soil moisture in spring varies with time. In all the years of observation it was considerably higher in forested fields than in the steppe. Every year in spring there is a considerable moisture deficit in the fields in the steppe. In the years when the moisture content in spring in the meter portion of the soil in steppe fields reaches the ultimate field moisture capacity, expectancy is 3%. In forested fields when the amount of soil moisture in spring is equal to the field moisture capacity, espectancy reaches 30%. Consequently, the spring moisture content in

---

[4] The coefficient of utilization of natural soil moisture contents is calculated, according to V.V. Kolpakov, as the ratio between the amount of moisture lost in a given layer during the growing period (in mm) and the total amount of productive moisture in the same soil layer in spring (sowing period).

Table 3

Coefficient of moisture utilization during the growing period of agricultural crops

Crop	Number of observations	Coefficient of moisture utilization		
		Minimum	Maximum	Average
Winter wheat	14	0,36	0,68	0,55
Spring wheat	14	0,21	0,76	0,59
Sunflower	6	0,50	0,69	0,62
Alfalfa	6	0,44	0,67	0,52
Black fallow[a]	10	0,11	0,34	0,17

[a] For black fallow - coefficient of unproductive moisture loss.

Table 4

Amount of moisture in spring in upper 1 m of soil in forested and steppe fields, mm

Amount of water in upper 1 m of soil in spring	Years of observation															Aver. for 15 yrs.
	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	
Forested field	334,7	380,3	369,2	318,5	370,0	374,0	306,9	304,5	322,0	360,0	278,0	345,0	345,0	351,0	348,0	347
Fields in the steppe	295,6	287,5	322,9	295,5	340,0	318,0	253,7	282,3	301,4	348,0	248,0	287,0	303,0	320,0	311,0	300
Difference in moist. amt.	39,1	92,8	46,3	23,0	30,0	56,0	53,2	22,2	20,6	12,0	30,0	58,0	42,0	31,0	37,0	47

Note: Comma represents decimal point.

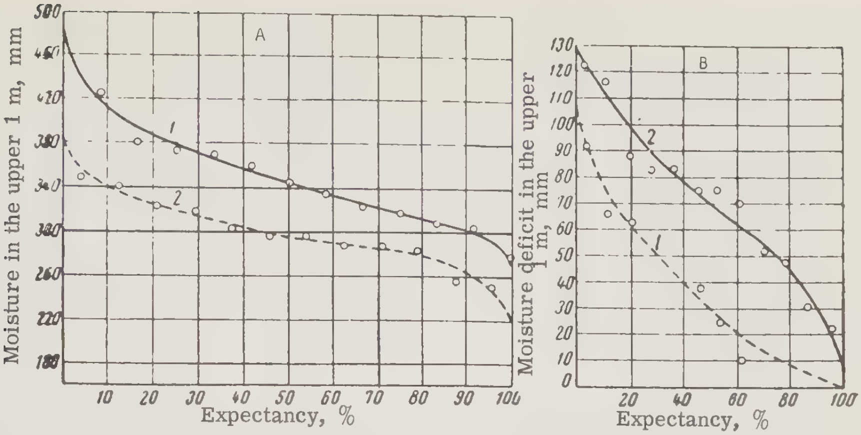

Fig. 3. - Expectancy curves of the total amount of moisture in the upper 1 m of soil in spring (after snow melting) in a forested field and in the steppe (A). Moisture deficit curves for the upper 1 m of soil in spring (after snow melting) in a forested field and in the steppe (B).

the meter layer of the soil in these fields is below the ultimate field moisture capacity in 70% of the years of observation.

At an expectancy of 50% (long-period average) the amount of moisture in the soil is 93% of the field moisture capacity. At 80% of field moisture capacity, expectancy is 85%.

Figure 3-B shows that the long-period average deficit (50% expectancy) is 32 mm in forested fields and 73 mm in steppe fields. Under steppe conditions there is a lesser or higher moisture deficit every year, in forested fields it is less important. The increase in soil moisture in forested fields occurs as a result of reduced meltwater runoff. In these fields more local runoff water penetrates into the soil than in fields in the steppe. Therefore the annual yield of agricultural crops in the forested fields of the Dokuchayev Institute is higher than in the steppe (2). Our calculations and experimental investigations on the wetting of the aerated zone of the soil in the Kamennaya Steppe showed that to compensate for the moisture deficit in this zone during the snow melting period in spring (after which water begins to seep through the soil and ground water begins to rise) requires an average of 324 mm of water per field, 208 mm for a forested field, and 273 mm for a forest belt (if the ground water is at a depth of 6-10 m).

As long-period observations show (the work of Basov (4) and our investigations), 4-100 mm of meltwater are retained in the fields (water contents in the snow minus runoff) during the snow melting period in steppe catchments (Osinov ravine), and an average of 23 mm for a long-time period (23 years). In the forested catchment of Lesnaya ravine (forest cover, 6%) runoff water retention varies from 24-141 mm and averages 58 mm. In the forested catchment of Selektsentr ravine (forest cover, 18%) meltwater retention varies from 50-155 mm from year to year and averages 93 mm. Consequently, in order to eliminate the moisture deficit in the aerated zone and cause water to seep through and the ground water to rise, a larger amount of water is required than is retained in catchments, even those having an extensive forest cover. Consequently, the position of Vysotskiy (7), and Rode (16, 17) on the existence in the steppe zone of a soil layer which is not being wetted during the infiltration of spring meltwater is true for conditions in the Kamennaya Steppe (for steppe and forested catchments). Ground water is fed by meltwater only if it is close to the surface (2-3 m). If the ground water is deep (6-10 m and more), it is recharged locally. Recharging is achieved in individual areas with "pot-holes"— relief depressions, saucers, sinkholes, and areas with a thick snow cover (in forest belts, at their edges, road shoulders, near buildings, etc.). Forest belts are places of intensified groundwater recharge, the water contents in the snow before melting vary from 300-500 mm and considerably exceed the amount of water necessary for wetting the soil through. Consequently, the soil in the forest belts is thoroughly wetted during the snow melting period and receives an ample recharge of water. Thus, forest belts irrigate themselves.

Conclusions

1. Soil moisture accumulates in the southeastern part of the Central Chernozem Belt from September to April. The amount of moisture is at a maximum in April. From May to July and sometimes August, i. e., the growing period of agricultural crops, soil moisture is lost by transpiration of plants and evaporation from the soil surface. Average data indicate that soil moisture is at a minimum in July, and in certain years in August. For several years the average soil moisture losses during the growing season were 115 mm in a spring wheat field, 125 mm in a winter wheat field, and 60 mm in fallow.

2. According to 8-year data (1948-1955), the soil layer from 0-150 cm accumulates on the average 64 mm of moisture from September to December, and only 30 mm during the winter and spring periods.

3. The coefficient of absorption for autumn and winter precipitation (September-December) varies rather sharply from year to year. In individual years (humid and cold) it reaches 0.7-0.8, while in years with a warm autumn it drops to 0.23-0.25. From 1948-1955 it averaged 0.48. The coefficient of absorption for winter-spring precipitation varied in 8 years from 0.3-0.85, and averaged 0.60. The total coefficient of absorption for autumn-winter and spring precipitation was 0.51.

4. The average coefficient of moisture accumulation for 8 years was 0.55 in a winter wheat field, 0.59 in a spring wheat field, 0.69 in a sunflower field, 0.52 in an alfalfa field, and 0.167 in black fallow. It varies rather sharply from year to year.

5. Forests around fields promote a fuller utilization of atmospheric precipitation (rain and snow). In 15 years the amount of moisture in the upper 1 m of soil in a forested field was 47 mm higher than in a field in the steppe. The difference between the amount of moisture in a forested and a steppe field varied from 92.8 mm (1945) to 12 mm (1953). The recharge of moisture in a forested field occurs as a result of the reduction of surface runoff.

6. During the snow melting period more meltwater is retained in the forested fields of Kamennaya Steppe than in fields in the steppe. A large amount of this water is spent on wetting the upper soil layers. Meltwater reaches the ground water only in places where the latter is close to the surface (2-3 m) and those with relief depressions, saucers, sinkholes, and areas of deep snow accumulation (in forest belts, at their edges, road shoulders, near buildings, etc.).

Received January 21, 1960

BIBLIOGRAPHY

1. ALEKSANDROV, N. P. 1953. Results and the outlook for the study of soil fertility in the Kamennaya Steppe. In the book: Problems of the grass-arable system in agriculture. Vol. 2. Izd. Akad. Nauk SSSR.

2. ALEKSANDROV, N. P. 1955. Introduction to the collection "Forest shelterbelts." Sel'khozgiz.

3. ANTIPOV-KARATAYEV, I. N. and G. M. KADER. 1953. Development of solonetzic processes in the soils of the Kamennaya Steppe. In the book: Problems of the grass-arable system in agriculture. Vol. 2. Izd. Akad. Nauk SSSR.

4. BASOV, G. F. 1949. Hydrological role of forest belts in the Kamennaya Steppe. Agrobiologiya, No. 1.

5. BURNATSKIY, D. P. and M. I. SUCHALKINA. 1949. The water regime of soils in the Kamennaya Steppe in drought years. Agrobiologiya, No. 1.

6. BURNATSKIY, D. P. and others. 1951. Change in microclimate and the fertility of soil. In the collection: Experimental introduction of the grass-arable system in the Kamennaya Steppe. Voronezh.

7. VYSOTSKIY, G. N. 1938. Hydrological and meteorological effect of forests. Goslestekhizdat, Moscow.

8. DOLGOV, S. I. 1946. Forms and states of soil moisture. Pochvovedeniye, No. 7.

9. DOLGOV, S. I. 1957. System of fall practices to increase the amount of soil moisture in the spring of 1953 in the steppe regions of the Altay Province. Zemledeliye No. 9.

10. ZONN, S. V. 1954. Material for the study of the water regime of chernozems under forest plantations and agricultural land use. Trudy Instituta Lesa Akad. Nauk SSSR. Vol. 15.

11. ZONN, S. V. 1954. Water regime of chernozems under a forest belt and a forest stand in the dry steppe. Trudy Instituta Lesa Akad. Nauk SSSR. Vol. 22.

12. KOLPAKOV, V. V. 1953. Irrigation of the major agricultural crops in the Central Chernozem Belt. Izvestiya Timiryazevskoy Sel'skokhozyaystvennoy Akademii. No. 1.

13. KOSTYCHEV, P. A. 1951. Drought control. Selected works. Izd. Akad. Nauk SSSR.

14. NIKANOROVA, N. N. 1953. Natural conditions in the Kamennaya Steppe. Voprosy travopol'noy sistemy zemledeliya. Vol. 2. Izd. Akad. Nauk SSSR.

15. PROTSEROV, A. V. 1948. Relation between runoff and precipitation accumulation and the saturation of soil in the autumn. Sovetskaya agronomiya, No. 2.

16. RODE, A. A. 1952. Soil moisture. Izd. Akad. Nauk SSSR.

17. RODE, A. A. 1949. Problem of the concept of soil hydromorphism. Pochvovedeniye, No. 10.

18. SHACHEKOV, I. A. 1949. The Dokuchayev-Dostychev-Vil'yams complex in the Kamennaya Steppe. Voronezh.

19. SUKHAREV, I. P. 1955. Influence of soil tillage on the runoff of meltwater and of shower water. Pochvovedeniye, No. 4.

20. FRANTSESSON, V. A. 1939. Forms of water composing field moisture capacity. Sovetskaya agronomiya, No. 1.

21. FRANTSESSON, V. A. 1949. Maximum hygroscopicity and bound water in chernozem soils. Trudy yubileynoy sessii, posvyashchennoy pamyati V. V. Dokuchayeva. Moscow-Leningrad.

DYNAMICS OF IRON
IN SOLONETZES OF THE TRANS-TISZA REGION OF HUNGARY

LASLO GEREI, Budapest

Processes of solonetz formation are widespread in the Trans-Tisza region of Hungary. In this area solonetzes and meadow soils are irrigated by flooding. Irrigation destroys the colloidal complex of these soils and the iron in them becomes mobile.

Many authors relate the migration of iron and solonetz formation to anaerobic conditions which develop under irrigation. In the specialized literature it is pointed out that the transition of iron into a mobile state is associated with reduction processes taking place in the soil (43, 12, 26, 23, 14). Schnitzer and Delong (37) explain the reduction of iron by the effect of organic substances on its compounds. Ignatieff (25) studied the reduction of iron during the flooding of sterile and non-sterile soils and concluded that it is caused by microbiological processes. Each of the foregoing assumptions has its proponents. The first is supported by Bloomfield (17, 19, 20, 21), and Schnitzer and Delong (37), and the second by Treitz (42), Sigmond (39), Szabolcs (40, 41), Viljamsz (43), Yarkov (15, 16), Ponnamperuma (35), and others. Gorbunov (3) points to the necessity of studying the dynamics of amorphous and crystalline forms of iron compounds. He established (4) that ferric oxide hydrates of various degrees of aging have various thermograms. Laatsch (33) showed that during the hydrolysis of clay minerals containing iron, ferric oxide is released which crystallizes, as ferrimetahydroxide does, in the form of hetite of ultramicroscopic size.

Many authors note a relationship between the solonetz process and the migration of iron. Antipov-Karatayev (1) studied the formation of the illuvial horizons in solonetzic soils. Sigmond (39), as well as Glinka (24) established that insoluble silicic acid accumulates in the A horizon of solonetzes while at the same time the amount of cations and sesquioxides decreases. The later accumulate primarily in the B horizon.

B. B. Polynov (6, 7, 8) studied the problem of salinization and desalinization in relation to weathering and the formation of secondary minerals. He indicates (9, 10) that active iron hydroxide possesses three major properties: 1) it can reversibly change its dispersion and is capable of producing a reversible gel; 2) it tends toward reduction and repeated oxidation and 3) it can enter a solution in the form of ions of ferrous iron.

Szabolcs (40), and Yarkov, Kaurichev, and Moddubnyy (16) believe that the iron cycle is one of the characteristic signs of solonetzization and solodization and agree with Sigmond (38) in that a "temporary excess wetting" is an important factor in solonetzization. They determined that mobile organo-mineral iron compounds form in solonetzic soils under the influence of anaerobic biochemical processes. Many authors pay attention to the iron cycle in relation to the sowing of rice during flooding (5, 35, 36, 27, 28, 29, 30, 31).

As we can see, various authors agree that: 1) the dynamics of iron is part of the process of solonetz formation; 2) irrigation by flooding affects the dynamics of iron; and 3) there is a close relationship between the dynamics of iron and the change of soil colloids.

Methods

It was first of all necessary to clarify the question of whether there is a relationship between the amount of easily soluble and mobile iron, and whether one can judge about the movement of iron in the soil from the number of its easily soluble compounds.

We investigated the distribution of iron soluble in 0.05-N sulfuric acid in the individual horizons of a meadow solonetz and its total content in this soil. The results of the analyses are given in Figure 1-A and B.

We are interested only in the relative difference between the curves and it is of no importance that the curves are of a different scale.

As we know, sesquioxides move from the A horizon of soils of the solonetz group into the B horizon where they precipitate and accumulate. The total amount of iron is least in the A horizon (Fig. 1-B), while it accumulates in the B horizon. It can be seen from Figure 1-A that the A horizon contains the maximum amount of mobile iron. Consequently, one may judge of the movement of this element by the amount of easily soluble iron and its change.

An 0.05-N solution of sulfuric acid was found most suitable for dissolving mobile iron when studying the meadow soils and meadow solonetzes of the Trans-Tisza region.

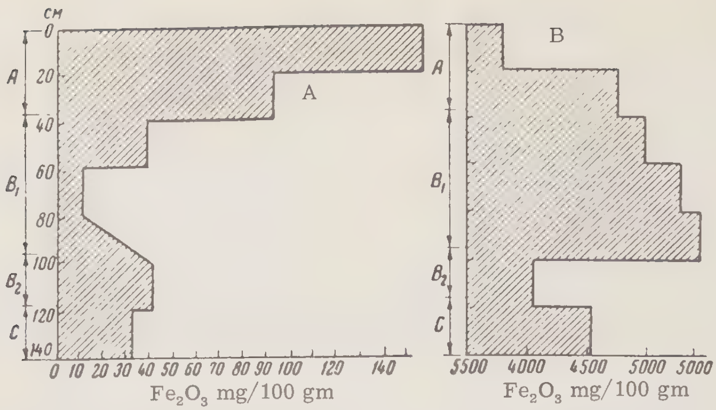

Fig. 1. - Distribution of total iron and iron removed in a 0.05-N H_2SO_4 extract. A - 0.05-N H_2SO_4; B - total.

According to the opinion of Yarkov (15, 16), and Rode (11, 12), the iron moves in the soil in the form of complex organo-mineral compounds which dissolve in diluted acids. Yarkov, Kulakov, Kaurichev, and Kopteva (14) used a 0.05-N solution of H_2SO_4 to dissolve mobile iron and this method gave satisfactory results in their investigations. In the opinion of Gedroyts (2) the colloidal complex of the soil is not being decomposed under the action of a 0.05-N solution of HCl. This conclusion is confirmed by the results of the investigations of Chernov (13), and Mitchell and Mackenzie (34).

We wanted to determine the bi- and trivalent iron in the extract and therefore we used sulfuric acid instead of hydrochloric acid, since the former has a smaller effect on reduction processes.

During the investigation of the influence of the concentration of hydrochloric and sulfuric acid on the amount of soluble iron it proved that with concentrations exceeding 0.05-N the amount of soluble iron increases. This shows that the adsorption complex is being decomposed at acid concentrations exceeding that used by us (Fig. 2). Proceeding from this it was found that a 0.05-N solution of sulfuric acid, as a weak solvent, was suitable for dissolving mobile iron in the soils of the Trans-Tisza region.

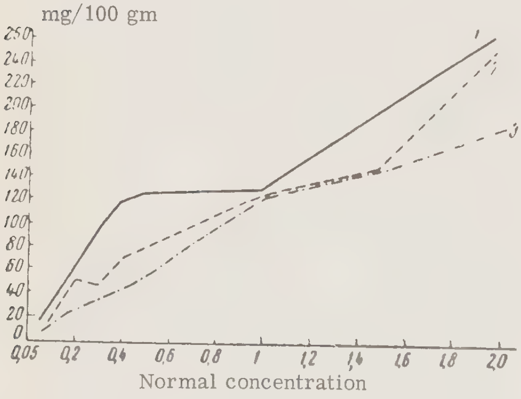

Fig. 2. - Relationship between the concentration of hydrochloric and sulphuric acid and the amount of dissolved iron.
1 - chernozem H_2SO_4; 2 - solonetz H_2SO_4; 3 - meadow soil HCl.

To determine the suitability of the method (especially for evaluating the dynamics of iron), we determined the variations of the results of determinations of easily soluble iron in the soil. The samples were taken from two profiles at a distance of 20 cm from each other. The deviations of the results did not exceed ±3% (See Table 1).

On one occasion samples were taken from four places at a distance of 20 cm from each other and arranged in the form of a square, but no greater deviations were noted. Two years of observation on the dynamics of soluble iron showed that its amounts sometimes differed by more than 100%, for instance during the determination of easily soluble iron in the A horizon of Profile 12 (Fig. 5-A). Thus, the variation in the amount of easily soluble iron in the soil proved to be much smaller than the dynamic changes of its content.

Iron was determined from a 0.05-N extract of sulfuric acid by means of salicylic acid and complexone III (22, 32). The amount of soluble iron (total amount of bi- and trivalent iron) was determined according to the following method: 10 g of dry soil is shaken with 250 cm³ 0.05-N sulfuric acid for an hour. If the soil has carbonates, the carbonate content is determined beforehand and the carbonates are neutralized with 1-N H_2SO_4 (0.05-N sulfuric acid is added first so that the soil would not come into contact with the more concentrated acid). Then this solution is filtered. The pH of the filtrate must be between 1 and 2. A drop of H_2O_2 and salicylic acid are added to a definite amount of filtrate in methyl alcohol. Iron salicylate of a purple color forms which is titrated

Table 1

Results of the determination of easily-soluble iron in the irrigated meadow solonetz from Sarvash, mg/100 g of soil. October, 1955

Depth, cm	Profiles		Depth, cm	Profiles	
	1	2		1	2
0—20	180,1	186,3	100—120	24,2	24,6
20—40	130,2	125,4	120—140	36,6	36,0
40—60	16,1	15,7	140—160	35,0	34,6
60—80	14,0	14,0	160—180	66,1	65,3
80—100	11,1	11,3	180—190	67,5	65,6

Note: Comma represents decimal point.

with complexone III until the solution becomes colorless.

Trivalent, easily-soluble iron is determined on another sample. The method differs from the foregoing in that 0.05-N sulfuric acid, saturated with carbonic acid, is used as a solvent to avoid the oxidation of bivalent iron, and no H_2O_2 is added to the solution.

The amount of bivalent iron is determined from the difference between the total amount of iron and the amount of trivalent iron.

Distribution of Easily-Soluble Iron in Various Soil Groups

Figure 3 shows the amount of total iron soluble in a 0.05-N solution of sulfuric acid and also the amount of iron oxide in the same extract. The hachured portion corresponds to bivalent iron and the clear portion to trivalent iron.

We can conclude that the distribution of soluble iron is approximately the same in meadow soils, there is a small accumulation of soluble iron in the upper 20 cm of solonetzic meadow soil, and a considerable accumulation of total soluble iron in the same layer of solonetz.

Thus, a relationship is established between the intensity of salinization processes and the amount of easily-soluble iron found in the upper layer of soil. There is a considerable amount of easily-soluble iron oxide in the C horizon of slightly solonetzic meadow soil which is associated with the process of gleization.

Investigations on strongly podzolized, slightly podzolized brown forest soil, brown forest, and humus-carbonate (rendzina) soils showed that there are differences between the accumulation of easily-soluble iron in the upper horizons of these soils and the degree of podzolization. There is a considerable amount of easily-soluble iron in the A horizon of strongly podzolized brown forest soil, while there is somewhat less easily-soluble iron in the slightly podzolized brown forest soil; there is no accumulation of iron in the upper horizon of brown forest soil. In humus-carbonate (rendzina) soils, where there is no leaching, the amount of easily-soluble iron is zero.

The absolute amount of easily-soluble iron in the meadow, solonetzic, and forest soils is not the same, because of the textural differences of these soils. Meadow and solonetzic soils are clayey, while forest soils are sandy. It means that the distribution of easily-soluble iron is determined by soil-forming processes, while its absolute amount depends on the texture of the given soil.

In the acid sandy soil from the Nir'shig rayon, easily-soluble iron is distributed evenly. There are no degradation processes in this soil.

In the solonchak-solonetz of the Danube-Tisza interfluve there is a more considerable accumulation of easily-soluble iron. The textures of the sandy soil from the Nir'shig and the solonchak-solonetz from the region between the Danube and Tizsa are approximately the same, but at the same time there is a great difference in the distribution of easily-soluble iron in them. This fact also shows that the movement of iron in the soil depends primarily from the nature of soil processes. In the bog soil from Kestkhey, where conditions are strongly anaerobic, there is more bivalent than trivalent iron.

The following conclusions can be made on the distribution of easily-soluble (mobile) iron in soils of individual groups. Its amount and distribution differ from horizon to horizon and show a close relation to soil formation processes. It is interesting to note that the amount of easily-soluble iron increases in the upper layer of those soils in which degradation processes (solonetzization and podzolization) take place. The absolute amount of iron is related to soil texture. The absolute amount of easily-soluble iron is higher in sticky clay soils. The ratio between bi- and trivalent iron in the 0.05-N extract of sulfuric acid points to the presence of aerobic-anaerobic conditions in the foregoing horizon when the sample was taken. Under aerobic conditions easily-soluble iron is in the trivalent form in the soil horizons, with little access to air it is primarily in the bivalent form.

Dynamics of Iron in Meadow Solonetzes

When studying the movement of iron one determination of the distribution of easily-soluble iron along the profile is not sufficient.

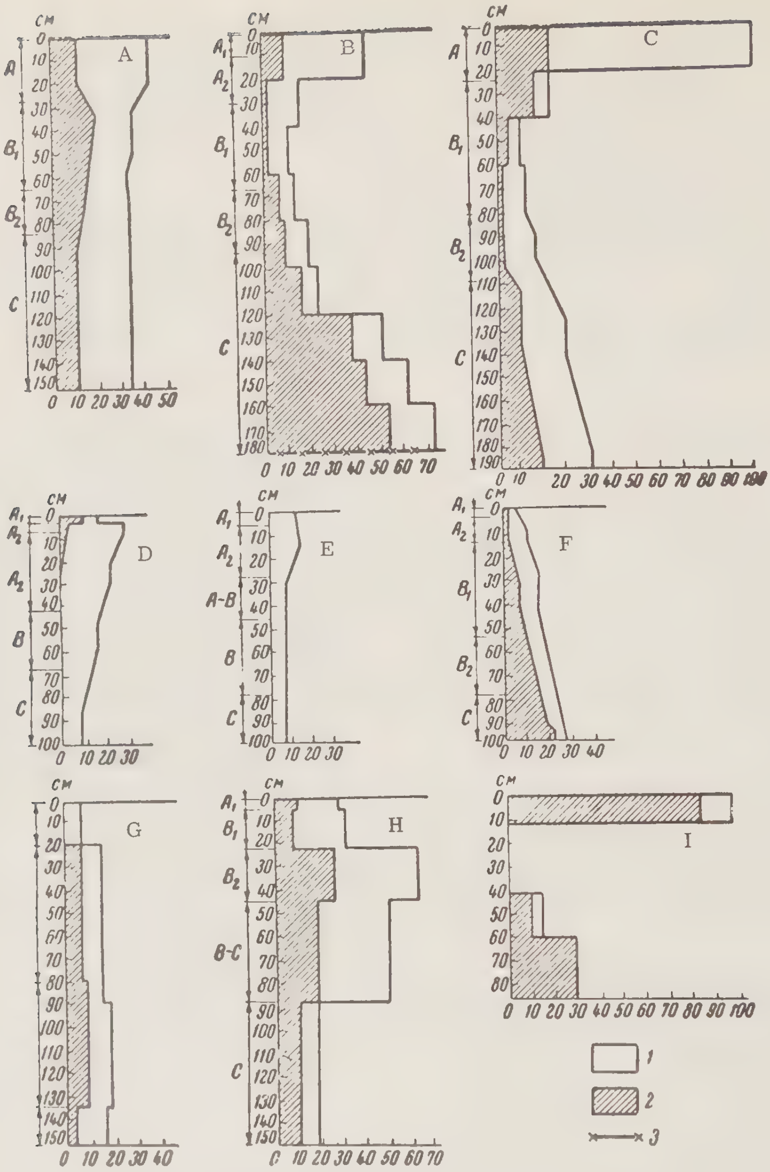

Fig. 3. - Distribution of easily-soluble iron in the major soil groups of Hungary.
Soil: A - typical meadow; B - slightly solonetzic meadow; C - solonetz; D - strongly podzolized brown forest; E - slightly podzolized brown forest; F - brown forest; G - acid sandy from Nired'khaz; H - solonchak; I - bog from Keetkhey. 1 - ferri and ferro; 2 - ferro; 3 - ground water. mg/100 g of soil are plotted along the abscissa.

To come to the right conclusions one must study the dynamics of iron with time. Such investigations were conducted at the experimental field of the Scientific-Research Institute of Irrigation and Rice Growing of the city of Sarvash. Soil samples were taken from such fields in which experiments on the growing of rice under crop rotation were conducted. During the time of observation (1954-1957) various crops were grown under rotation in these fields. Profile 6 was under a mixture of legumes and grasses during the first year and under winter wheat in the second year. Profile 12 was under rice the first year and under spring barley the second; Profile 14 was under red clover both years; and Profile 8 under rise both years.

Samples were taken the first year (1954-1955) from three profiles: 16, 14, and 12; and the second year (1956-1957) from four profiles: 16, 14, 12 and 8, three times a year. The samples were taken at depth intervals of 20 cm to a depth of 2 m.

Judging by their morphology and chemical data the profiles belong to the following soil groups: Profile 16, to deeply solonetzic meadow soil; Profile 14, to secondary solonetz; and Profile 8, to deep meadow solonetz.

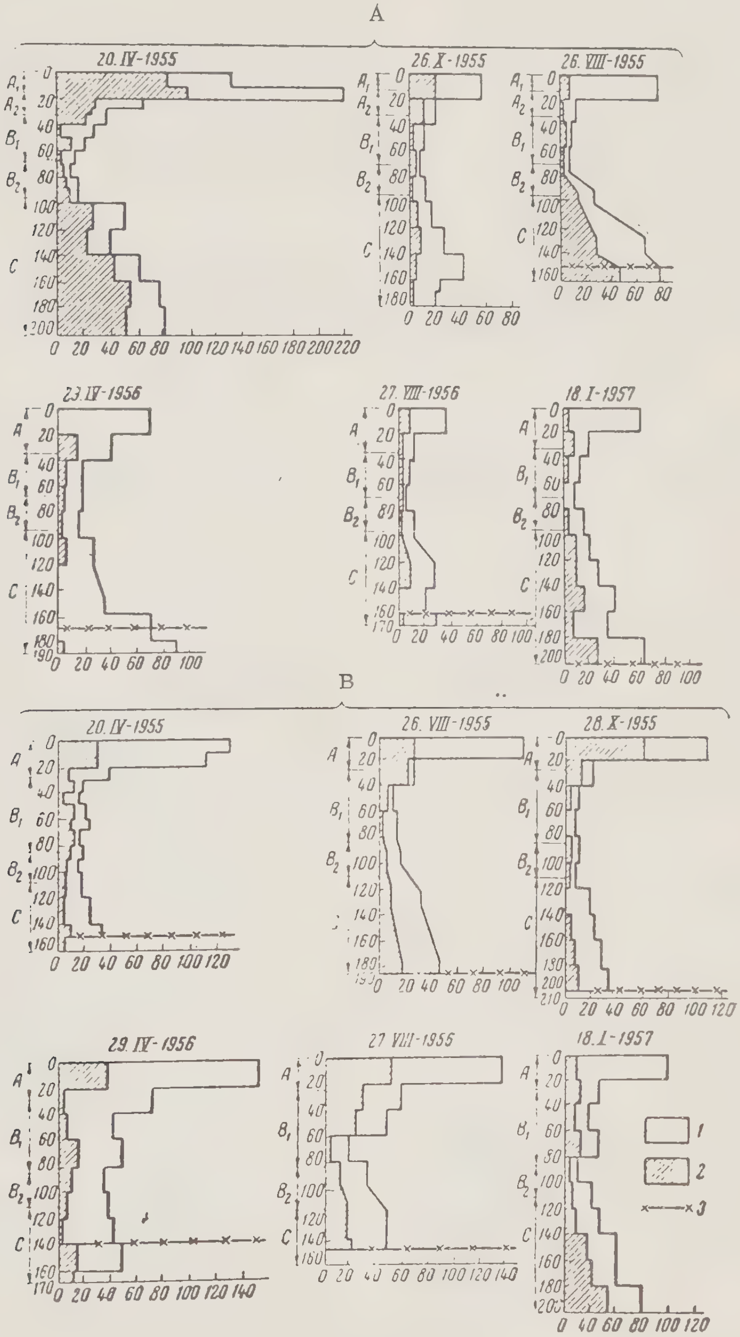

Fig. 4. - Dynamics of iron in Profile 16 from Sarvash (A). Same in Profile 4 (B).
1 - ferri + ferro; 2 - ferro; 3 - ground water. Fe_2O_3 is plotted in mg/100 g of soil along the abscissa.

During 2 years the dynamics of iron in individual profiles was distinguished by the following features.

Profile 16 (Fig. 4A). Deep solonetzic meadow soil. There is little easily-soluble iron in the A horizon as compared to the other profiles. An exception are samples taken in April 1955, when a large accumulation of easily-soluble iron was observed. This shows that in order to obtain results it is not sufficient to determine the amount of easily-soluble iron only once, it must be determined many times.

The meadow solonetz from Profile 14 (Fig. 4-B) is characterized by a more intense dynamic of iron than is meadow soil. This points to a close relation between solonetzization processes and the migration of iron.

Profile 12 (Fig. 5-A) is also a meadow solonetz, but the field in which it is located was irrigated the first year, as a result of which more easily-soluble iron formed in the upper layer of the soil than in the meadow solonetz (Profile 14) which had not been irrigated. The degree of solonetzization of these two profiles is the same, therefore, the more intense dynamics of iron in Profile 12 is caused by irrigation by flooding. Irrigation in June and August, 1955 caused an increase in the total amount of easily-soluble iron and easily-soluble iron oxide in the A horizon of this profile. The amount of mobile iron did not decrease, even in October, 1955. It rose sharply again in April of the following year as a result of excess wetting in spring. This points to the prolonged influence of flooding irrigation. A sharp decrease in the movement of iron occurred at the same place the following summer without irrigation.

The dynamics of iron was different in Profile 8 (irrigated meadow solonetz, Fig. 5-B). Under the influence of irrigation, the amount of easily-soluble iron increased in the A horizon of this soil in October and not in summer. Below we will give an explanation for this phenomenon.

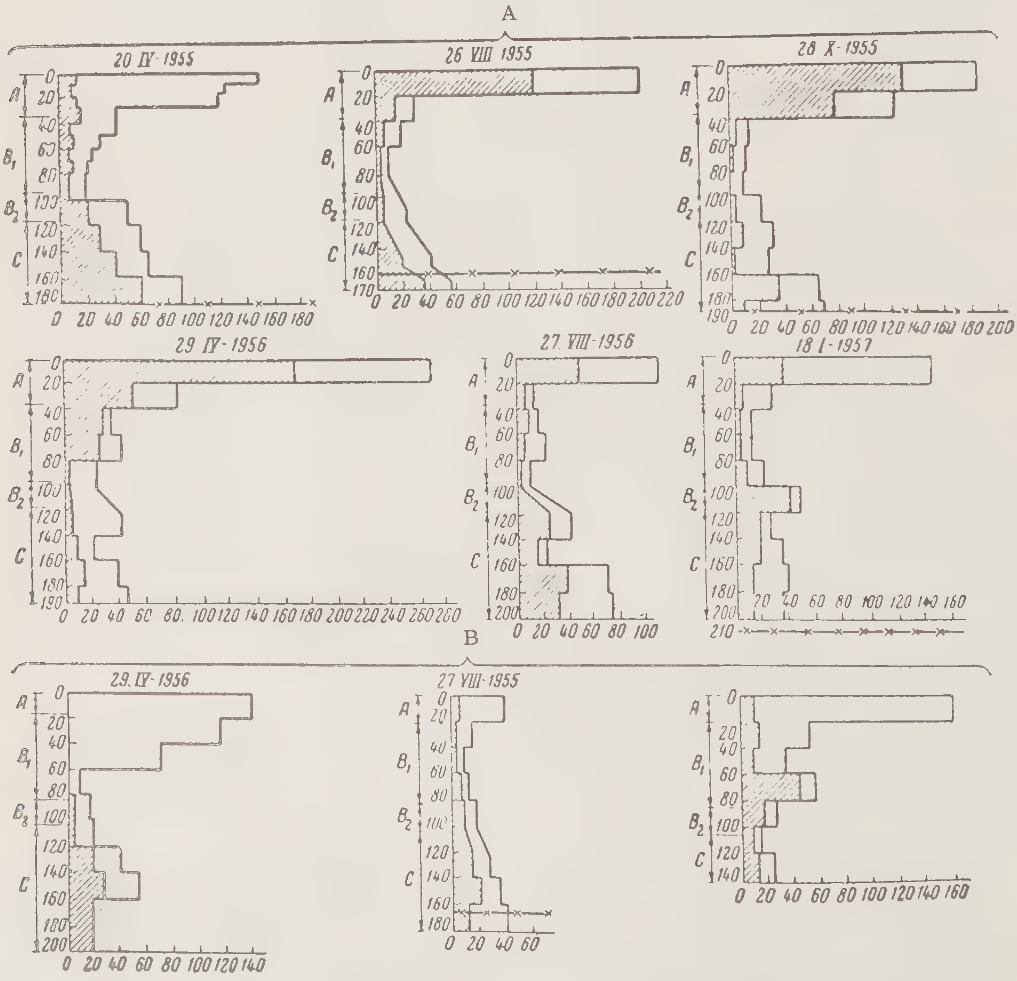

Fig. 5. - Dynamics of iron in Profile 12 from Sarvash (A). Same in Profile 8 (B). (For symbols see Fig. 4).

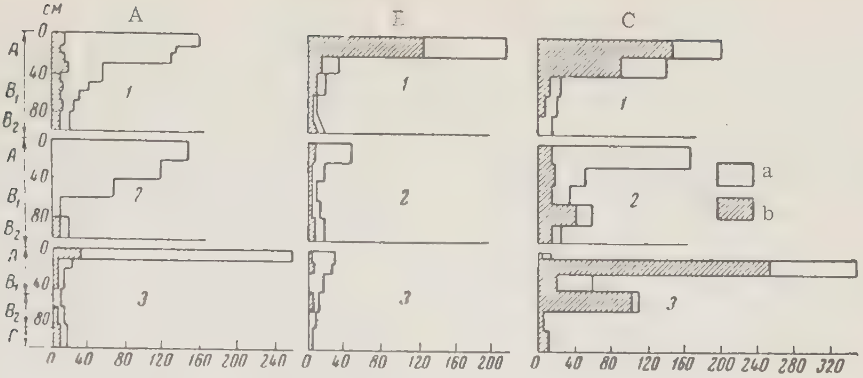

Fig. 6. - Comparison of the dynamics of iron in sulfate solonetz (Profile 12) and bicarbonate solonetz (Profile 8 from Sarvash and Profiles 301 and 302 from Kopanch).

A - April; B - August; C - October. 1 - Profile 12; 2 - Profile 8; 3 - Profile 301: a - ferri + ferro; b - ferro.

A pronounced increase in the mobility of iron was observed in the upper horizons of all three profiles of saline soils (Fig. 5 and 6) under the influence of excess wetting in spring and autumn. It is interesting to note that the dynamics of iron in the upper horizons was associated with the degree of salinization of the soil, which is not true of the lower (B and C) horizons of the soil.

The mobility of iron in Profile 8 differs from that in Profile 12, even though both these soils are meadow solonetzes and are irrigated by flooding. These profiles differ only in the composition of salts. Profile 12 has a large amount of sulfates, while Profile 8 contains bicarbonates. We were interested in the question whether the mobility of iron was determined by the composition of salts. Therefore, we determined the mobility of iron in two bicarbonatic meadow solonetzes, which were also irrigated by flooding. The iron cycle in the sulfatic Profile 12 from Sarvash, the bicarbonate Profile 8 from Sarvash, and Profiles 301 and 302 from Kopanch, are compared in Figure 6. This comparison allows the following conclusions to be drawn. The intensity of the migration of iron in sulfatic and bicarbonate, irrigated solonetzes differs. The amount of mobile iron increases greatly in August in the upper horizon of sulfatic solonetzes under the influence of irrigation by flooding. Easily-soluble iron accumulates somewhat later in the upper horizons of bicarbonate solonetzes than it does in sulfatic solonetzes. The degree and nature of salinization apparently influence the dynamics of iron in the saline soils of rice fields.

It is interesting to note that we found more easily-soluble iron in April and October in the two profiles from Kopanch, than in the profiles from Sarvash. This is apparently due to the fact that rice has been grown for a long time as a single crop under flooding in the fields of Kopanch. Consequently, a single crop grown for a long time causes strong solodization.

Conclusions

1. Easily-soluble (mobile) iron in meadow soils and meadow solonetzes may be determined with 0.05-N sulfuric acid.

2. The amount of easily-soluble (mobile) iron and its distribution along the horizons differ in soils of various groups and are closely related to soil-forming processes. In such soils where degradation takes place (solonetzization and podzolization) the amount of easily-soluble iron greatly increases in the upper horizons.

3. According to 2 years of observation, the iron cycle is more pronounced in solonetzes than in solonetzic meadow soils.

4. The processes of salinization and iron migration have a seasonal dynamics.

5. The relation between the movement of iron and salinization processes is a complicated one. The migration of iron in the lower horizons of solonetzes is related to the parent material and the movement of ground water.

6. It can be assumed that the migration of iron and the microbiological processes in the soil, which depend on oxidation-reduction conditions, are closely associated with each other.

7. Irrigation by flooding greatly enhances the migration of iron in solonetzes. After irrigation is discontinued, the movement of iron is slowed down considerably under the influence of crop rotation and soil melioration.

8. The migration intensity of iron differs in equally irrigated sulfatic and bicarbonate solonetzes. Easily-soluble iron compounds accumulate later in the upper horizons of bicarbonate solonetzes than they do in sulfatic solonetzes. There is more easily-soluble iron in the upper horizons of irrigated solonetzes occupied for a long time by rice than in recently irrigated solonetzes.

Received May 27, 1960

BIBLIOGRAPHY

1. ANTIPOV-KARATAYEV, I. N. 1939. Problem

of the genesis of illuvial horizons in solonetzes. Pochvovedeniye, No. 7.

2. GEDROYTS, K. K. 1930. Bulleten' pochvoveda. No. 1.

3. GORBUNOV, N. I. 1952. Minerals of the fine fraction of soils, their distribution pattern, and method of study. Pochvovedeniye, No. 10.

4. GORBUNOV, N. I. 1954. Reports given at the V International Congress of Soil Scientists. Izd. Akad. Nauk SSSR.

5. NEUNYLOV, V. A. 1955. Theory and practice of the increase of the productivity of soils in the rice fields of Maritime Province. Moscow.

6. POLYNOV, B. B. 1912. Problem of the formation of secondary minerals in the ortstein horizons of the soil. Ezhegodnik Geologicheskogo Ministerstva Rossii. 14 (9).

7. POLYNOV, B. B. 1915. Secondary minerals in the ortstein horizons of the soil. Izvestiya pochvennogo komiteta. No. 2.

8. POLYNOV, B. B. 1917. Basis of erosion and nature. Izvestiya pochvennogo komiteta.

9. POLYNOV, B. B. 1933. Processes of salinization and desalinization. Report of the lower Volga expedition of the Academy of Sciences of the USSR.

10. POLYNOV, B. B. 1956. Selected works. Izd. Akad. Nauk SSSR.

11. RODE, A. A. 1937. Soil-forming process. Izd. Akad. Nauk SSSR.

12. RODE, A. A. 1955. Soil science. Goslesbumizd. Moscow.

13. CHERNOV, V. A. 1952. The author of soil acidity. Pochvovedeniye, No. 10.

14. YARKOV, S. P., YE. V. KULAKOV, I. S. KAURICHEV, and Z. F. KOPTEVA. 1950. Formation of iron oxide and the characteristics of the phosphate regime in sod-podzolic soils. Pochvovedeniye, No. 8.

15. YARKOV, S. P. 1954. Formation of podzolic soils. Izd. Akad. Nauk SSSR.

16. YARKOV, S. P., I. S. KAURICHEV, and M. N. PODDUBNYY. 1956. Experimental study of the genesis of solonetzes and solods. Izvestiya sel'skokhozyaystvennoy akademii im. Timiryazeva.

17. BLOOMFIELD, C. 1950. Some observations on gleying. J. Soil Sci.

18. BLOOMFIELD, C. 1953. Sesquioxide in mobilization and cly movement in podzolized soils. Nature, v. 172.

19. BLOOMFIELD, C. 1953. A study of podzolization. Parts I-II, J. Soil. Sci. v. 4.

20. BLOOMFIELD, C. 1954. A study of podzolization, J. Soil Sci. v. 5, (Part III-IV-V).

21. BLOOMFIELD, C. 1955. The solution-reduction of ferric oxide by aqueous leaf extracts the role of certain constituents of the extracts.

22. GEREI, L. 1956. Adatok hazai talajtipusaink könnyen oldható vas és aluminum tartalmanak vizsgálatához és jelentősegehez. Agrokémia és Talajtan. 2 sz.

23. GILLESPIE, L. 1920. Baktériumkulturák és vizjárta talajok redukciós potenciálja. Soil. Sci. 9 sz. (Fotokópia).

24. GLINKA, K. D. 1914. Die Tyen der Bodenbildung ihre Klassifikation und Geographische Verbreitung. Berlin.

25. IGNATIEFF, V. 1941. Determination and behavior of ferrous iron in soils. Soil Sci. v. 51.

26. ISLAM, M. A., M. A. ELAHI. 1954. Revision of ferric iron to ferrous iron under water logged conditions and its relation available phosphorus. J. Agric. Sci. 45, I.

27. KAWAGUCHI, K., Y. MATSUO. 1955. Distribution of free oxides along soil profiles in time series of dry rice fields in polder lands of Kojuma-Basin. Soil and Plant Food, 2, 1955.

28. KAWAGUCHI, K., Y. MATSUO. 1955. Relationship between the amounts of free oxides and total oxides in profiles of dry rice fields in polder lands of Kojima-Basin. Soil and Plant Food, v. 2.

29. KAWAGUCHI, K., Y. MATSUO. 1956. Movements of active oxide in dry paddy soil profiles. VI^{-e} Congr. Intern. Sci. Sol Paris, 533.

30. KAWAGUCHI, K., Y. MATSUO. 1957. Re-investigation on distribution of active and inactive oxide along soil profiles. Soil and Plant Food, v. I.

31. KAWAGUCHI, K., T. HATTORI, K. WALKI. 1957. Some chemical and mineralogical studies on profiles of dry rice fields of polder land in Kojima-Basin. Soil and. Plant Food, v. 1.

32. KÖRÖS, E. 1953. Komplexometriás meghatározások. Magyar Kémikusok Lapja. 8. sz.

33. LAATSCH, W. 1954. Dynamik der mitteleuropäischen Mineralböden, Verlag Dresda Leipzig.

34. MITCHELL, B. D., R. C. MACKENZIE. 1954. Removal of free iron oxide from clays. Soil Sci. 77.

35. PONNAMPERUMA, F. N. 1955. (Doktori

disszertáció) Cornell University, Feb.

36. PONNAMPERUMA, F. N. R. BRADFIELD, and M. PEECH. 1956. The chemistry of submerged soils in relation to the growth of rice. VI. Congr. Intern. Sci. Sol. Paris, Commis. 4.

37. SCHNITZER, M., W. A. DELONG. 1954. Note of relative capacities of solutions obtained from forest vegetation for mobilization of iron. Canadian J. Agric. Sci. v. 34.

38. SIGMOND, E. 1923. Hazai szikesek és megjavitasi módjaik. M. T. A. Budapest.

39. SIGMOND, E. 1934. Altalános talajtan. Budapest. Szerö Kiad.

40. SZABOLCS, I. 1954. Hortobády talajat. Mezógazd. Kiadó. Budapest.

41. SZABOLCS, I. 1956. Ontözött talajaink degradációja. M. T. A. Agr. Tud. Oszt. Közlemenyei. 3-4 sz.

42. TREITZ, P. 1924. A sós és szikes talajok természetrajza. Budapest.

43. VILJAMSZ, V. R. 1950. Talajtan. Akadémiai Kiado. Budapest.

CELLULOSE DECOMPOSITION IN THE ZONAL SOILS OF TADZHIKISTAN

A. F. ZAKHARCHENKO, Soil Science Institute, Academy of Sciences, Tadzhik SSR

The biological process of cellulose decomposition in the soil has been studied by many investigators: Vinogradskiy (1), Omelyanskiy (15), Imshenetskiy (3), Kononova (6), Mishustin (8), Teplyakova (21), and others.

Information on the intensity of cellulose decomposition, and the amount and species composition of cellulose-decomposing microorganisms in sierozem and certain other soils of Central Asia and Kazakhstan is contained in the works of Mishustin and Pod"yapol'skiy (9), Kvasnikova (4), Yelkina (2), Lazarev (7), Teplyakova (20, 21, 22, 23), Popova (17), Kiseleva, Paletskaya and Sokolova (5), Paznitsyna (18), and others.

Ye. A. Raznitsyna studied virgin and old irrigated light sierozems of the Vakhta valley in Tadzhikistan. Her data indicate that cellulose decomposers develop in virgin, non-irrigated sierozem primarily in April and May, which is associated with favorable temperature and moisture conditions during this time of the year. Microbiological life dies away in virgin light sierozems in summer because of dryness and in winter because of the relatively low soil temperature. Cellulose-decomposing bacteria were found only in the upper 0.50 m of these soils and predominated in the upper layers. The period of activity of cellulose-decomposing bacteria in the irrigated light sierozems is more prolonged. Here their number increases from spring to summer and reaches a maximum in July. Many fungi, belonging to the genera Fusarium, Penicillium, and Clodosporium and a certain amount of mycobacteria are found among the cellulose-decomposing microflora of light sierozems in winter and spring. The latter predominate in spring and become the main decomposers of cellulose. In summer actinomycetes appear in the cellulose of irrigated light sierozems.

Until recently almost all the investigations on cellulose-decomposing microorganisms in the soil were made in the laboratory on definite artificial media under a conditionally set optimum temperature and moisture. Thus only relative data on the amount and activity of these microorganisms in various soils were obtained. However, their activity directly under natural conditions remained insufficiently studied, while in Tadzhikistan it was not studied at all.

Great attention was paid to the study of the life activity of microorganisms under natural conditions by Kholodnyy (24, 25, 26), Vinogradskiy (1), and Novogrudskiy (10, 11, 12, 13). Pybalkina and Kononenko (19) studied the active microflora of the soil by placing growth glasses in the soil (under natural conditions) according to the modified method of N. G. Kholodnyy.

As participants of complex investigations on the process of soil formation in the main groups of Tadzhikistan soils, we were faced with the problem of determining the nature and intensity of cellulose decomposition under natural conditions.

Method of Investigation

Beginning in 1954 we used a method by which cellulose (filter paper) was placed directly in the soil to various depths (down to 2 m). After a given time (depending on the purpose of the investigation) the paper was removed and the state of the cellulose, its decreased weight, and the composition of microorganisms were studied in the laboratory. Technically it was done in the following way. A 10 x 10 cm sheet of filter paper was numbered, weighed, and glued with melted 2% aqueous agar to 11 x 14-cm glass plates. The size of the glass was slightly larger than that of the filter paper so that edges were left free to handle the plates during removal and analysis without touching the paper. The filter paper, glued to the glass, was dried, a number was written with special ink on the reverse side of the glass, and the plates thus prepared were sterilized in an autoclave.

The glass plates with the cellulose were placed into vertical cuts in the soil, or niches made in the walls of freshly dug soil profiles, usually at a depth of 5-15 cm, 40-50 cm, and 190-200 cm. The experiment was usually replicated three times for each horizon. After the filter paper was placed in the soil, the walls of the cuts were thoroughly smoothed with a sterile soil knife. The space back of the plate was filled with the soil removed from the cut. After the plates were placed in all the horizons, the trench was backfilled with the soil removed from it. The plates were usually left 40, 120, and more days in the soil (in high-mountain soil the plates with the cellulose were left in one case

Table 1

Results of the mathematical treatment of data on the decrease in cellulose weight, % of initial weight

Experimental treatment	No. of determinations, n	Arithmetical av., M	Square root deviation of the mean $\sigma=\sqrt{\left(\frac{\Sigma a^2}{n}-b^2\right)\frac{n}{n-1}}$	Standard error of the mean $m=\frac{\sigma}{\sqrt{n}}$	Accuracy index $P=\frac{m\cdot 100}{M}$	Variation coefficient $V=\frac{\sigma\cdot 100}{M}$	Standard error of the differ. bet. means $D=\frac{M_1-M_2}{\sqrt{m_1^2+m_2^2}}$
Glued with aqueous agar	15	17,1	10,1	2,61	15,3	59,1	1,4
Wetted with sterile water	15	22,3	10,01	2,59	11,6	44,9	

Note. a^2 - deviations squared from the origin of moments; arithmetic mean of deviations "a" from the origin of moments.

Note: Comma represents decimal point.

Table 2

Major long-period climatic data[a] and certain information on the soils of Tadzhikistan (data from the laboratory of the Soil Science Institute)

Soil	Elevation, m	Total mean daily temperatures for a year, 0° C	Annual amount of precipitation, mm	Hydrothermal coefficient[b]	Amount of roots in the layer from 0-50 cm, metric tons/ha	Amount of humus, % at a depth, cm 0—10	40—50	190—200
Light sierozem (Ak-Gaza)	460	6351	230	0,4	9,9	1,5	0,4	0,3
Typical sierozem (Obi-Kiik)	580	5840	363	0,6	21,9	1,9	0,7	0,3
Dark sierozem (Urta-Boz)	850	5402	611	1,1	29,5	2,9	1,1	0,4
Typical cinnamon-brown soil (Takob)	1650	3431	1428	4,2	60,1	10,2	2,9	0,9
High-mountain sod-meadow soil (Anzob)	3380	—584	259	—4,4	35,0	6,2	1,5	—

[a] According to the data of the Hydrometeorological Service of Tadzhikistan.
[b] According to G. T. Selyaninov, the hydrothermal coefficient 10 · A/B, where A is the annual precipitation in mm, and B is the temperature sum for the same period.

for 327 days).

When the plates with the cellulose were removed from the soil they were delivered to a laboratory where the state of the cellulose, its color, the degree and nature of its decomposition, the population and outer appearance of the formed colonies were described in detail, and where the colonies of microorganisms were examined under the microscope, separated, and placed into test tubes with an agarized medium with strips of filter paper for the further purification of the cultures and their determination.[1] The most characteristic plates with the cellulose were photographed. Then the filter paper was removed from the glass and, after thorough purification and treatment by the Omelyanskiy (14) method, was weighed and the magnitude of the decomposition of the cellulose was calculated in percent of its initial weight.

(Footnote 1 in next column)

---

[1] The genus of the separated fungi was determined by the author in the Alma-Ata Division of Microbiology, Soil Science Institute, Academy of Sciences, Kazakh SSR, under the supervision of the chief of the Division, Z.F. Teplyakova.

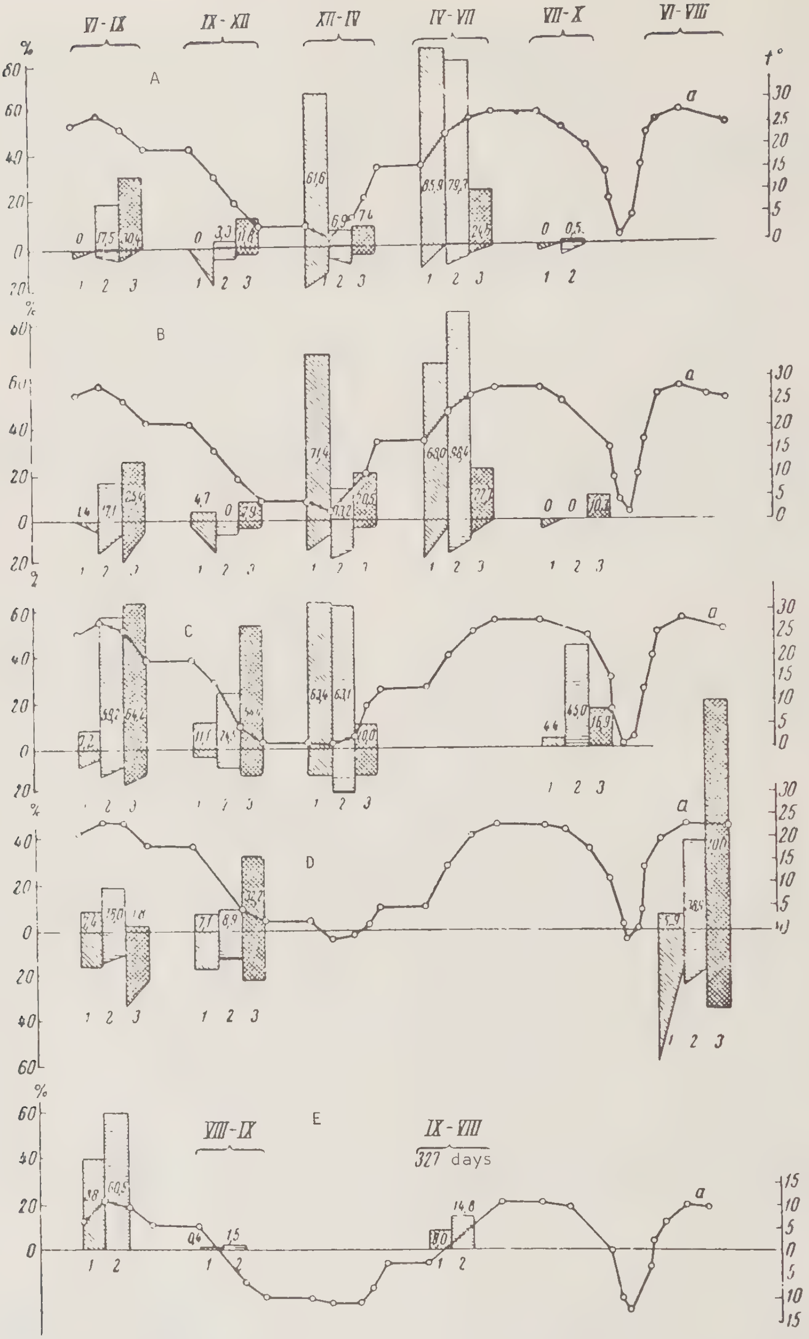

Fig. 1. - Intensity of the decomposition of cellulose by microorganisms in virgin soils by seasons, %

A - light sierozem; B - typical sierozem; C - dark sierozem; D - typical cinnamon-brown soil; E - high-mountain sod-meadow soil.

Decomposition is plotted upward from zero; soil moisture is plotted downward: a - mean monthly air temperatures, °C. Depth, cm: 1 - 5-15; 2 - 40-50; 3 - 190-200.

To determine the influence of agar with which the cellulose was glued on its decomposition in the soil we made a special experiment. Fifteen plates each with cellulose glued with aqueous agar, and non-glued cellulose (wetted with sterile water) were placed in the soil under identical conditions. The results of the experiment after mathematical treatment are given in Table 1, which shows that their standard deviations (σ) and the mean errors ($\pm$ m) are practically equal. The accuracy indices of the experiment (P) are close for both treatments, while the difference in the means (D) is insignificant, since it is less than three. From this one may conclude that it makes no difference whether the filter paper is glued to the glass with aqueous agar or not for the comparative determination of the decomposition of cellulose by microorganisms in the soil. The gluing of the filter paper to the glass with aqueous agar has many advantages, since it insures a better preservation of its remains when removing it from the soil, especially when it is greatly decomposed.

The great advantage of the method consists in that it allows one to study the microorganisms on cellulose in a live state. The colonies, which are clearly visible on the white paper, are easily examined under the microscope either directly on the plate, or after they are separated in a pure culture. The large size of the plate allows one to observe how the colonies of microorganisms are distributed, how the cellulose changes, and what is responsible for its decomposition.

We verified the reliability of the data obtained on the intensity of cellulose decomposition in various soils under natural conditions by calculating the degree of accuracy of the experiment by statistical method. The calculations show that a threefold repetition of the experiment assures, in the majority of cases, a satisfactory experimental accuracy and a small standard error.

The accuracy of the experiment (P) with virgin light sierozem varies from 1-12; that with recently irrigated and old irrigated plowed light sierozem, from 8-16; with typical sierozem (virgin and plowed), from 1-16; with dark sierozem, from 2-26; with a typical cinnamon-brown soil, from 1-47; and with high-mountain sod-meadow soil, from 16-24. The mathematical treatment of the foregoing material indicates that the distribution of the intensity of cellulose decomposition by microorganisms varies little in each soil studied. The variability of the distribution increases from light sierozem to typical cinnamon-brown soil, which is apparently associated with the increasing content of organic matter and the variability in the generic and chemical composition of vegetation.

Since we conducted our investigations and observations simultaneously with a group of soil scientists on the same soil profiles, it gave us the opportunity to obtain data on the characteristics of the soils studied. Climatic and other major information on the soils studied are given in Table 2.

The results of our experiments are summarized and shown in Figure 1. Because of the varying duration of the experiment in individual seasons, the data on the decomposition of cellulose by microorganisms in the soil (in percent of initial weight) were averaged for 3 months of each season for easier comparison. Figure 1 shows data on soil moisture at the beginning and end of the experiment and air temperature (according to data of the Hydrometeorological Service).

Results of Investigations

The results of the investigations show that favorable conditions for the decomposition of cellulose occur only in the upper layers of light, typical, and dark virgin sierozems of southern and central Tadzhikistan which are moist and warm in spring. In the remaining seasons this process is strongly repressed or altogether absent, at the beginning of summer and up to the beginning of winter because of a deficiency in moisture, and in winter because of the lack of warmth. This can be seen from the fact that the decomposition of cellulose was intense only in spring (XII-IV, IV-VII), while during observations in summer, autumn, and winter (VI-IX, VII-X, IX-XII) the process was either absent or very weak (Fig. 1).

The most favorable and only possible time for the decomposition of cellulose in high-mountain sod-meadow soil is the short summer, from mid-July to mid-August, since in the experiment from the beginning of July to the end of September, 1954 (80 days), 33.8% of the initial weight of cellulose decomposed; in the other experiment (from mid-August to the end of September) there was almost no decomposition; while in the experiment which lasted from the end of September, 1954 to mid-August 1955, i.e., almost a year, about the same amount of cellulose decomposed as from July to September, 1954 (32.9%). It must be assumed that in this case also decomposition took place only from July to mid-August.

The absence of conditions for the decomposition of cellulose for most of the year in high-mountain sod-meadow soil is confirmed by long-period data on monthly mean air temperatures. Air temperature varies from -7.9°C to +2.1°C in spring; from 5.8 to 9.6°C in summer with a maximum in July (10.5°C); from +5.0°C to -6.8°C in autumn; and is always negative, below -10°C, in winter (see Fig. 1).

In all virgin soils investigated (from light sierozem to typical cinnamon-brown soil the activity of cellulose decomposition increased from the lower to the upper horizons in winter-spring and spring-summer, which is apparently determined by optimum hydrothermal conditions in the upper soil layers in spring and also by the better supply here of energy material for the microorganisms. In summer, summer-autumn, and autumn-winter, the intensity of cellulose decomposition increases in the opposite direction, from the upper to the lower horizons. The reason for this is apparently the relatively higher moisture and more favorable temperature in the lower layers of the soil in this time of the year. Actually, the investigations showed that when the temperature of the soil is high in summer and autumn, moisture in the upper layers of light sierozems often drops much below maximum hygroscopicity,

i. e., to a limit at which the development of even xerophytic actinomyces and fungi is impossible (10). The deeper soil layers have usually a higher moisture content in these seasons.

In comparing the intensity of cellulose decomposition in virgin soils at various elevations in Tadzhikistan, we can distinguish the following pattern. In light and typical sierozem, located in the hottest, dry belt, intense cellulose decomposition of a short duration takes place only in spring when the upper soil layers have still enough moisture. At the beginning of summer the intensity of decomposition in the upper layers decreases sharply and then stops completely; in the deeper layers it continues in summer.

At higher elevations with dark sierozems and then cinnamon-brown soils the intensity of cellulose decomposition drops somewhat in spring, but then it lasts for a much longer period and does not stop in summer. In the high-mountain belt, at an elevation of 3380 m, the amount of atmospheric precipitation decreases to the amount in the light sierozem belt and simultaneously the temperature drops sharply. Therefore, even though the moisture content of high-mountain sod-meadow soil remains higher than in light sierozems, higher plants and microorganisms suffer from a deficiency in heat during most of the year. A more or less intense decomposition of cellulose in the soil takes place here only during a short period in summer. There is practically no decomposition in the remaining part of the year.

A comparison of the intensity of cellulose decomposition in various soils during the period of most favorable hydrothermal conditions shows that 85%-100% of the cellulose in sierozem soil decomposes during the 90 days of spring, while 30%-50%-60% of the cellulose in high-mountain sod-meadow soil decomposes during the summer, the optimum time for this zone.

Microflora Participating in Cellulose Decomposition

Investigations on cellulose decomposition both under natural as well as laboratory conditions show that the most active role in this process is played by fungi and bacteria. Actinomyces also play a certain role in it. It is difficult to say without special investigations whether fungi or bacteria play a predominating role in the decomposition of cellulose. We paid more attention to the composition of the fungal flora in the experiments on cellulose decomposition than to the bacterial flora.

Fungi are widespread in the soils of Tadzhikistan and are very varied. Some of them are energetic cellulose decomposers, while others are weaker; they are the constant, or occasional companions of cellulose microorganisms. The fungi which participate in the decomposition of cellulose in Tadzhik soils belong to the following genera: Gliobotrys, Chaetomium, Trichoderma, Aspergillus, Trichurus, Hormidvium, Cladosporium, Monotospora, etc. According to the data of Omelyanskiy (15), Teplyakova (21), Pidoplichko (16), and Novogrudskiy (13), individual species of the foregoing fungi are more or less strong decomposers of cellulose. Especially energetic in the decomposition of cellulose are the species of the genus Gliobotrys, which hydrolyze cellulose to sugar. Gliobotrys is found in all the soils studied, and its amount increases from light sierozems to typical cinnamon-brown soil. This fungus accumulates primarily in the upper soil layers. The largest amounts of Chaetomium are found in the lowest horizons of the soils studied. It sometimes covers the plates completely at a depth of 40-50 cm and 190-200 cm. The genetic composition of fungi found by us in various soil groups during the study of the decomposition of cellulose are presented in Table 3.

Actinomyces predominate quantitatively in the lower horizons of the soils. Bacterial decomposition of cellulose is of great importance. One may sometimes observe the strong decomposition of cellulose removed from the upper soil layers and the formation of a colorless or colored slime. The bacterial decomposition of the filter paper at a depth of 40-50 cm and 190-200 cm was mostly achieved by nonpigmented colonies of bacteria and was accompanied by the formation of dense, small holes, being the result of the disappearance of cellulose.

Conclusions

1. The method of studying one of the most important processes — the decomposition of cellulose directly in the soil — allows one to determine the biological activity of individual soil groups during definite time intervals and to establish a relation between the microbiological decomposition of cellulose and ambient conditions.

2. The investigation of the intensity of the biological decomposition of cellulose in various soils of Tadzhikistan according to vertical zones showed that it depends to a great extent on climatic and, in particular, hydrothermal conditions and changes sharply from season to season as a result of soil moisture and temperature changes at various elevations.

3. The only possible time for the intense decomposition of cellulose in the upper layers of sierozem soils is the moist, warm spring; in the more moist, but less warm cinnamon-brown soils, the decomposition of cellulose proceeds less intensely than in the sierozems in spring, but it is more prolonged and more extensive; in the high-mountain sod-meadow soil, cellulose decomposes only during the short and comparatively warm summer.

4. The intensity of cellulose decomposition increases from the bottom to the upper layers of soil profiles in spring. In summer, autumn, and winter, on the contrary, the process intensifies toward the deeper soil layer, where moisture and temperature conditions are more favorable and stable.

5. The principal decomposers of cellulose are fungi and bacteria. Fungi are widespread and varied in the soils of Tadzhikistan.

Received November 25, 1959

Table 3

Generic composition of fungi found on filter paper during experiments on decomposition under natural conditions

Depth, cm	Soil
	Light, virgin sierozem (Ak-Gaza)
0–10	Gliobotrys, Chaetomium (Ch. subterraneum, Ch. globosum)
40–50	Gliobotrys, Chaetomium (Ch. subterraneum, Ch. globosum, etc.) Mono-Mucor, Aspergillus, Cladosporium
190–200	Gliobotrys, Chaetomium (Ch. subterraneum, Ch. globosum, etc.) Hormiscium, Trichoderma, Cladosporium, Aspergillus
	Newly irrigated light sierozem (Ak-Gaza)
20–30	Gliobotrys
40–50	Gliobotrys, Chaetomium subterraneum
	Old irrigated light sierozem (Nikhi station, Vakhta valley)
0–10	Gliobotrys, Mucor
40–50	Gliobotrys, Chaetomium (Ch. spirale, etc.), Monotospora
190–200	Gliobotrys, Chaetomium (Ch. spirale, etc.), Monotospora
	Typical virgin sierozem (Obi-Kiik)
0–10	Gliobotrys
190–200	Gliobotrys, Chaetomium (Ch. subterraneum, Ch. globosum, etc.)
	Typical plowed sierozem (Obi-Kiik)
0–10	Gliobotrys, Chaetomium (Ch. subterraneum, etc.), Myrothecium, Alternaria, etc.
40–50	Gliobotrys, Chaetomium subterraneum
100–110	Gliobotrys
150–160	Chaetomium subterraneum
	Dark virgin sierozem (Urta-Boz, Gissar valley)
0–10	Gliobotrys, Chaetomium
40–50	Gliobotrys, Chaetomium (Ch. subterraneum, etc.), Stachybolicus
190–200	Gliobotrys, Chaetomium, Helminthosporium
	Dark plowed sierozem (Urta-Boz, Gissar valley)
20–30	Gliobotrys, Chaetomium subterraneum
40–50	Gliobotrys
	Typical virgin cinnamon-brown soil (Takob)
0–10	Gliobotrys
40–50	Gliobotrys, Chaetomium subterraneum, Trichurus, Cephalosporium, Penicillium, Macrosporium, Stemphylium, Alternaria
190–200	Gliobotrys, Chaetomium, Rhizopus, Aspergillus, Mono-Mucor
	Virgin, high-mountain sod-meadow soil (Anzob)
5–20	Gliobotrys
35–45	Gliobotrys, Chaetomium, Cephalosporium

BIBLIOGRAPHY

1. VINOGRADSKIY, S. N. 1952. Microbiology of soil. Izd. Akad. Nauk SSSR.

2. YELKINA, O. G. 1954. The nature of mineralization processes in virgin sierozems. Trudy Sredne-Aziatskogo gosudarstvennogo Universiteta, Novaya seriya, No. 60, biologicheskiye nauki. No. 19. Tashkent.

3. IMSHENETSKIY, A. A. 1953. Microbiology of cellulose. Izd. Akad. Nauk SSSR.

4. KVASNIKOV, YE. I. 1957. Microbiological characterization of soils. Khlopchatnik. Vol. 5. Akad. Nauk UzSSR.

5. KISELEVA, N. T., L. N. PALETSKAYA,

and Ye. A. SOKOLOVA. 1958. Microflora of meadow-solonchak soils in the zone of the middle stretches of the Amu-Dar'ya River. Trudy Instituta botaniki Akad. Nauk TurkmSSR. Vol. 4.

6. KONONOVA, M. M. 1951. Problem of soil humus and modern tasks of its study. Izd. Akad. Nauk SSSR.

7. LAZAREV, S. F. 1954. Bio-organomineral complex of irrigated soils of Central Asia. Tashkent.

8. MISHUSTIN, YE. N. 1938. Mycobacteria decomposing cellulose. Mikrobiologiya. No. 7.

9. MISHUSTIN, E. N. and O. P. POD"YAPOL'SKAYA. 1953. Microbiology of soils in the Kara-Alma sovkhoz. Trudy Pochvennogo instituta im. Dokuchayeva. Vol. 39.

10. NOVOGRUDSKIY, D. M. 1946. Microbiological processes in the soils of semi-deserts. Mikrobiologiya, 15 (3).

11. NOVOGRUDSKIY, D. M. 1949. Natural and cultured forms of soil microorganisms. Izv. Akad. Nauk Kazatskoy SSR, Seriya mikrobiologicheskaya. No. 5.

12. NOVOGRUDSKIY, D. M. 1956. Soil microbiology. Izd. Akad. Nauk KazSSR.

13. NOVOGRUDSKIY, D. M. 1959. Soil humus and microbiological factors of its formation. Alma-Ata.

14. OMELYANSKIY, V. L. 1940. Practical instructions on microbiology. Izd. Akad. Nauk SSSR.

15. OMELYANSKIY, V. L. 1953. Fermentation of cellulose 1895-1913. Selected works. Vol. 1. Izd. Akad. Nauk SSSR.

16. PIDOPLICHKO, N. M. 1953. Fungous flora of coarse forage, Kiev.

17. POPOVA, YE. G. 1958. Microbiological characterization of takyrs and takyr-like soils. Izv. Akad. Nauk SSR, Seriya biologicheskaya. No. 6.

18. RAZNITSYNA, YE. A. 1947. Microorganisms in the soils of the Vakhta valley and their role in the fertility of the soils. Soils of the Vakhta valley. Izd. Akad. Nauk TadzhSSR.

19. RYBALKINA, A. V. and YE. V. KONONENKO. 1957. Microflora of soils in the European USSR. Izd. Akad. Nauk SSSR.

20. TEPLYAKOVA, Z. F. 1949. Cellulose-decomposing fungi in the soils of Kazakhstan. Izvestiya Akad. Nauk KazSSR, Seriya pochv. No. 76, vyp. 5.

21. TEPLYAKOVA, Z. F. 1952. Aerobic cellulose-decomposing microorganisms in the soils of Tadzhikistan. Trudy Instituta pochvovedeniya Akad. Nauk Kazakhskoy SSR, Vol. 1.

22. TEPLYAKOVA, Z. F. 1955. Factors determining the dynamics of cellulose-decomposing microorganisms in soils. Izv. Akad. Nauk Kazakhskoy SSR, Seriya biologicheskaya, No. 9.

23. TEPLYAKOVA, Z. F. 1959. Aerobic microorganisms and the mobilization of organic matter in mountain and piedmont soils of the Ketmen' range. Trudy Instituta mikrobiologii i virusologii Akad. Nauk Kazakhskoy SSR. Vol. 3.

24. KHOLODNYY, N. G. 1935. Methods of directly observing the microflora of soil. Mikrobiologiya, 4 (2).

25. KHOLODNYY, N. G. 1936. Investigation of the microflora of soil by culturing silt soil. Mikrobiologiya, No. 5.

26. KHOLODNYY, N. G. 1949. In nature and in the laboratory. Izd. Mosk. obshch. ispytateley prirody, Moscow.

METHODS

UPWARD MOVEMENT OF SUSPENDED MOISTURE IN SOILS OF THE STEPPE GROUP

L. G. BALAYEV, Laboratory of Hydrogeological Problems, Academy of Sciences of the USSR, North Caucasus Division, Stavropol'

The water regime of the soil is one of the most important factors determining the type of soil formation process. A non-leaching type of water regime is characteristic of steppe soil formation (7). In the regions with steppe soils autumn-winter-spring precipitation accumulates in the upper layer of the soil in the form of sorbed-suspended moisture (2, 11), which plays an essential role in the life and development of plants. During the growing period suspended moisture is lost by the plants not only on transpiration, but also on physical evaporation and the movement of water vapor into the deeper soil layers. Quantitatively the losses of suspended moisture on evaporation from the surface considerably exceed the losses resulting from the movement of vapor into the lower soil layers. Therefore the problem of the physical evaporation of suspended moisture in steppe soils is of great practical importance.

The main principles of the process of evaporation of suspended moisture in various soils were studied only recently by Rode (10, 11), Bol'shakov (4, 5), Abramova (1), Letunov (9), Burov (6), and others.

A. A. Rode (2, 11) distinguishes the following major cases of the retention of suspended moisture in soils:

1. Structureless sandy soils. Suspended moisture is of the wedge, capillary-suspended type and cannot move to the evaporation front. 2. Microstructural clay loam and silty soils. Suspended moisture is of the sorbed-suspended type. In the moisture interval from minimum moisture capacity to the capillary interruption point, suspended moisture moves rather easily to the evaporation front under the influence of sorption forces, from the thicker films of sorbed moisture toward the thinner films. 3. Clay loam and clay soils with a granular blocky structure. Suspended moisture belongs to the interaggregate, capillary-suspended type. Only that part of the moisture can move toward the evaporation front which is wedged at the points of contact between aggregates. 4. Structureless or slightly structured fine-textured soils. Suspended moisture is of the sorbed-suspended type. It is capable of moving slowly toward the evaporation front under the influence of sorption forces. At the capillary interruption point only strongly bound water is left in the soil.

In the present article we do not propose to discuss the process of evaporation of suspended moisture for all the foregoing cases, but only for the second case, that of microstructural clay loam and silty soils.

Method of Investigation

The hydrological area in which the investigations were made is located in the eastern part of the Cis-Caucasus, in the region of the high steppes of the Terek-Kuma interfluve. The climate of the region is dry and hot. The amount of precipitation is 340 mm. The ground water is located at 29 m. The soils are chestnut on coarse, silty clay loams. The maximum depth of wetting of the soil by atmospheric precipitation is 2.5 m. Soil moisture in the stagnant horizon varies from 6% at a depth of 3.0 m to 11% at a depth of 26 m in the vicinity of the upper boundary of the capillary fringe of ground water.

To conduct the investigation a virgin plot 10 x 10 m was leveled and diked. A trench 6 m deep was dug in its center. Two pore moisture tensiometers were placed in the walls of the trench at depths of 0.7 m and 3.5 m.

The moisture tension gages, designed by the author, operated on a principal similar to that of the Kornev apparatus (8) for measuring the suction force of the soil, but were equipped with special devices for collecting and removing the liberated air from the system (Fig. 1). The chambers with gages were placed in the soil in such a manner that the porous diaphragms were in full contact with the undisturbed soil. Water from the chambers seeped into the soil until the tension of the liquid in the chambers was equal to the tension of water in the soil pores. Gages were connected to the chambers by means of vacuum rubber hoses. The measuring device of the upper gage was an ordinary pair of piezometric tubes (Fig. 1), while the lower gage was connected to a self-recording vacuum gage of the type B. C. C. —410, filled with a liquid. The air escaping through the porous diaphragm and liberated from the water was collected and removed from the system by Mariotte vessels attached to the wooden facing of the trench.

After the gages were installed in the trench,

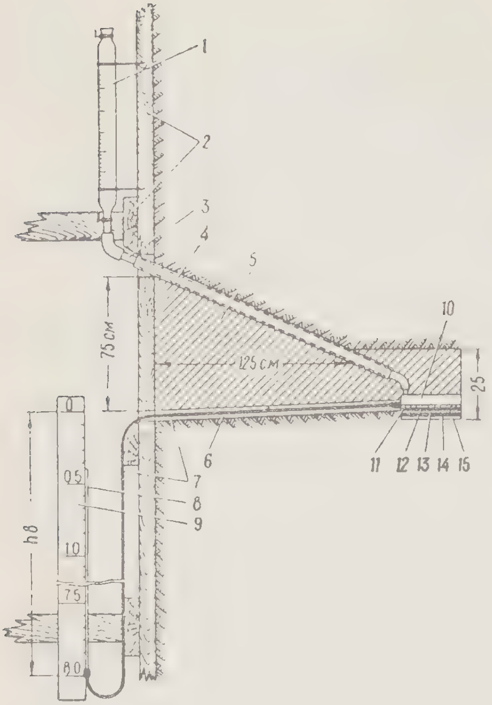

Fig. 1. - Tension gage for measuring water in pores.
1 - Mariotte vessel for collecting air penetrating into the chamber; 2 - trench support; 3 - glass tube 8 mm in diameter; 4 - metal tube 1" in diameter; 5 - fill of moist soil; 6 - metal tube 1" in diameter; 7 - thick-walled rubber hose; 8 - glass tube 8 mm in diameter; 9 - measuring scale; 10 - chamber of the gage; 11 - bronze grate; 12 - copper net 0.2 mm in diameter; 13 - medium grained sand; 14 - porous diaphragm; 15 - soil paste coating.

the plot was irrigated. The amount of water used was designed to wet the soil to minimum moisture capacity to a depth of 4.0 m. After the water had been absorbed by the soil, the dynamics of the change in the moisture of the soil and the tension of pore moisture at the upper and lower boundaries of the wetted layer were measured. Soil samples for moisture determination were taken 4 times from the trench 2, 8, 20, and 90 days after wetting, and the pore moisture tension was determined at various time intervals with the moisture tensiometers.

Results of the Investigations

Figure 2 gives the results of soil moisture determinations at various time intervals after wetting. These data show that the content of suspended moisture decreased sharply during the time of the experiment throughout the 4 m of wetted soil. A certain part of the moisture was lost as the wetting boundary moved downward, whereby its rate of movement, which was rather considerable in the first days after wetting, decreased sharply at the end of the experiment. The major part of suspended water was lost in physical evaporation.

The investigations of Rode, Abramova, Bol'shakova, and others showed that suspended moisture moves upward, toward the evaporation front, primarily in the liquid form. The problem of the nature of forces governing the upward migration of suspended water is of considerable interest. To answer this question, let us examine the curves of the change in the moisture tension in the pores near the upper and lower boundaries of the wetted soil layer. Data in Figure 3 show that the moisture tension near the evaporation surface increased sharply in the first days of the experiment (Fig. 3, curve 1). The tension in the lower part of the wetted layer was increasing much more slowly (Fig. 3, curve 2). At all times during the experiment the moisture tension near the evaporation surface exceeded that in the lower part of the wetted soil layer. This fact indicates that the upward migration of moisture toward the evaporation front occurs as a result of a sharp increase of the suction force of the soil in the upper part of the soil wetted to minimum moisture capacity.

The work of Rode (11) shows conclusively that suspended moisture is retained in the soil because of sorption forces. Individual, small volumes of free water are separated from each other by plugs of bound water which form in the narrow portions of soil pores and interfere with the downward flow of moisture. As we know (1, 2, 11) suspended moisture moves rather rapidly upward toward the evaporation surface. At the same time the resorption of moisture downward is very slow at the lower boundary of the soil layer wetted to minimum moisture capacity in the presence of a sharp transition between wet and dry soil and a considerable moisture gradient (11). If one assumes that the movement of moisture is governed in both cases by sorption forces alone, such as difference in the rate of movement of suspended moisture would be difficult to explain. Let us discuss this problem in more detail, using experimental data.

The author made experiments in 1956 on the filtration of water in finely-textured clay loams under the influence of the moisture tension gradient (3). The investigations were made with the apparatus shown schematically in Figure 4. The instrument consists of two chambers A and B, similar in design to the moisture tension gages. A soil sample, placed into ring K, was pressed against the porous diaphragms of the chambers and insulated from the surrounding air by sealing the joints with paraffin. The movement of water through the soil sample was caused by the difference in the water tension in chambers A and B, which was achieved by placing vessels F and G at various levels. The air displaced from the soil during filtration collected in vessel D and was periodically removed.

Table 1 shows the results of several experiments made on one sample of compacted fine clay loam. In all experiments the tension gradient remained constant during filtration (with

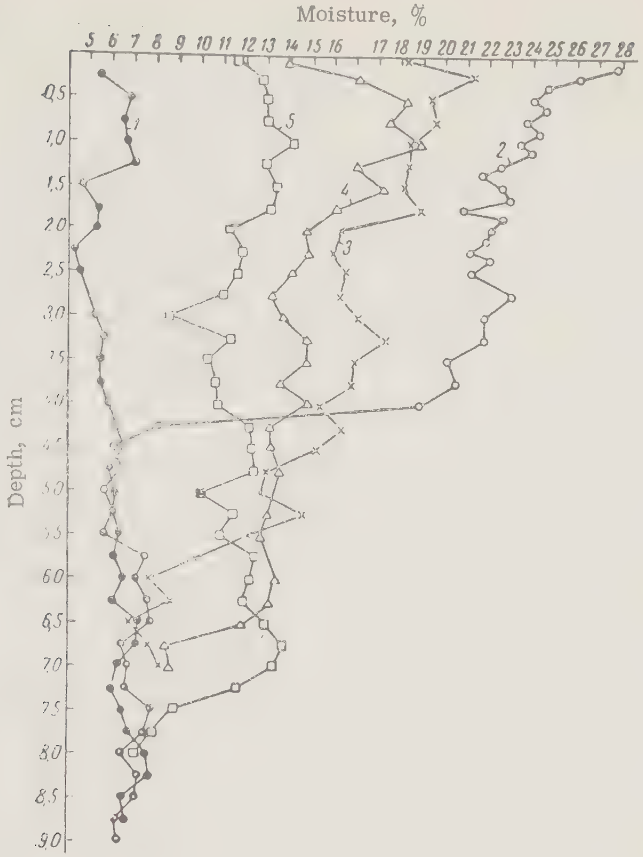

Fig. 2. - Change in the moisture content of the soil on evaporation of suspended moisture:
1 - before wetting. After wetting for: 2 - 2 days; 3 - 8 days; 4 - 20 days; 5 - 90 days.

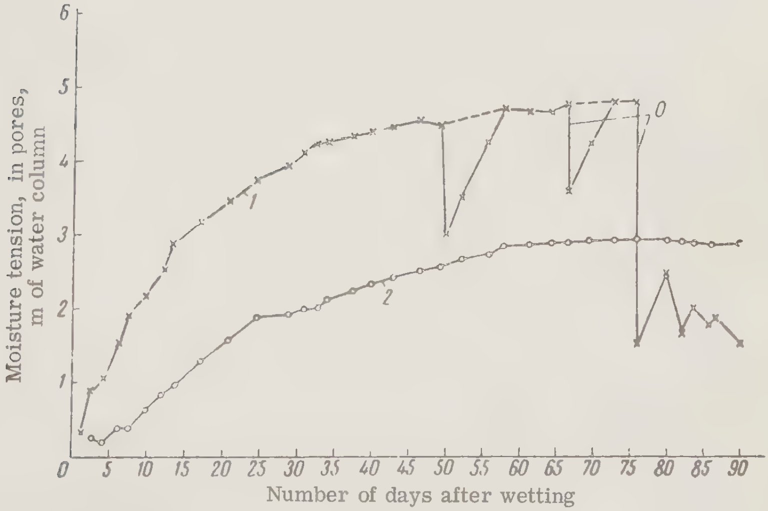

Fig. 3. - Moisture tension in pores near the upper and lower boundaries of the wetted soil layer.
1 - gage at a depth of 0.7 m; 2 - gage at a depth of 3.5 m; 0 - air entering the porous diaphragm of the gage.

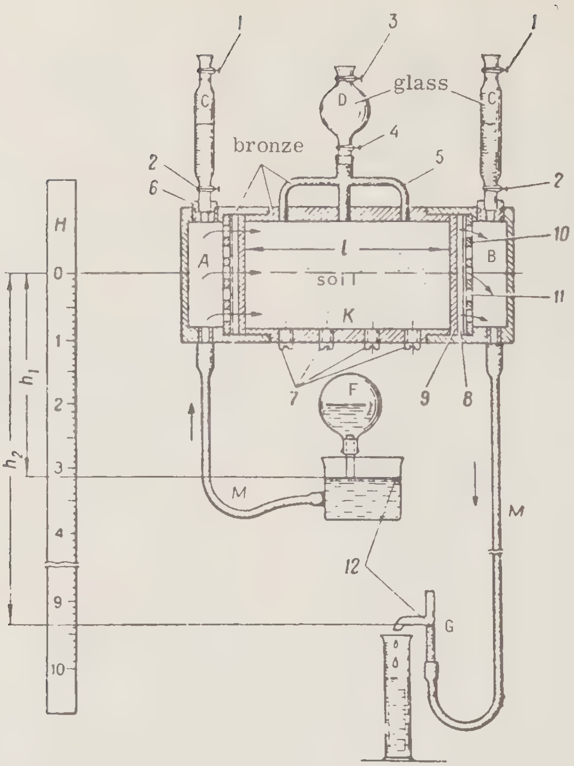

Fig. 4. - Diagram of apparatus for studying the movement of moisture in water-saturated and partially wetted soils.
1, 2, 3, 4 - stop cock; 5 - outlets; 6 - bronze sleeve; 7 - openings with stoppers (opened when infiltration of moisture into partially wetted soil is studied); 8 - medium-grained sand; 9 - porous diaphragm; 10 - bronze net; 11 - grid; 12 - level of the liquid.

Table 1

Results of experiments on the filtration of water through fine clay loams

Ex. No.	Water tension in chamber		Differ. between tensions $(h_2 - h_1)$	Average tension $h_{cp} = \frac{h_1 + h_2}{2}$	Filtration rate V_f, cm/day
	A h_1	B h_2			
	In cm				
3	50	90	40	70	3,09
7	200	240	40	220	4,16
11	300	340	40	320	5,08
51	400	440	40	420	7,41

Note: Comma represents decimal point.

the same tension drop in chambers A and B), but the average tension in the filtering water was varied:

$$h_{cp} = \frac{h_1 + h_2}{2}.$$

The data in Table 1 show that as the tension in the filtering water increased, the filtration rate increased considerably. For instance, with a water tension h_1 = 50 cm and h_2 = 90 cm in chambers A and B, respectively, the filtration rate was V_f = 3.09 cm/day. With water tensions of h_1 = 400 cm and h_2 = 440 cm, the filtration rate is considerably higher and reaches 7.41 cm/day, even though in both cases filtration took place under the same tension gradient.

We assume that this fact is determined by the gradual "removal," or thinning of the layers of lyosorbed water at the surface of soil particles when the moisture tension in the pores increases, and the increase of the active diameter of the soil pores in which the moisture moves. A detailed theoretical and experimental substantiation of this conclusion is given by Balayev (3). In the case of the upward movement of suspended moisture toward the evaporation front, it apparently also becomes more mobile as a result of the "removal" of the films of bound water at the surface of soil particles. In this case the sharp increase in the moisture tension in the vicinity of the evaporation surface (Fig. 3) must lead to the elimination of a certain amount of plugs of bound water in the upper part of the soil layer wetted to minimum moisture capacity. As a result a certain portion of sorbed-suspended moisture in clay loam soils gradually changes into the capillary state (first in large and then in smaller pores) during the evaporation of suspended moisture and moves not only under the influence of sorption forces, but also under that of meniscus forces. That may be the precise explanation of the high rate of movement of suspended moisture toward the evaporation front.

We showed earlier that the upward movement of suspended moisture is determined by a sharp increase in the suction force of the soil in the vicinity of the evaporation surface. The fact that the moisture tensions in the upper and lower portions of the wetted layer differ greatly in the same soil under almost identical moisture conditions is of great interest (Fig. 3). Without attempting to give a full explanation to this fact, let us discuss certain of our ideas on this problem only with respect to meniscus forces.

Let us take a Jamin capillary, which clearly reproduces the periodical changes of the transverse cross section of a pore, as a model for a soil pore. Figure 5 shows three cases of the distribution of the capillary meniscus in a Jamin capillary (diagrams I, II, and III). In all three cases the angle of wetting (angle θ in Figure 5) is of the same magnitude. If the capillary meniscus is located in the narrow portion of the Jamin capillary (diagram III), the radius of curvature of the meniscus will be:

$$R_3 = \frac{d_K}{2\cos\theta} \qquad (1)$$

Using the simplest geometrical transformations, we obtain: for case I

$$R_1 = \frac{d_K}{2\cos\left(\theta - \frac{\alpha}{2}\right)} \qquad (2)$$

for case II

$$R_2 = \frac{d_K}{2\cos\left(\theta - \frac{\alpha}{2}\right)} \qquad (3)$$

where α is the angle of convergence or divergence of the walls of the Jamin capillary; and d_K is the diameter of the capillary at the location of the meniscus.

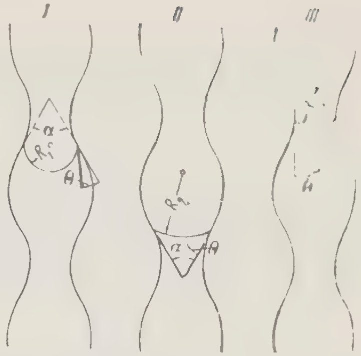

Fig. 5. - Diagrams (I, II, III) of the position of the capillary meniscus in a Jamin capillary.
α- angle of convergence of the capillary walls; θ - angle of wetting; R_1, R_2, R_3 - radius of curvature of the capillary meniscus.

The foregoing formulas show that the radius of curvature of the capillary meniscus depends not only on the diameter of the capillary tube at the place where it is located, but also on the magnitude of the angle of convergence or divergence of the walls of the capillary. Various magnitudes of the angle α (Fig. 5) in various cross sections along the Jamin capillary may lead to a great change in the curvature of the capillary meniscus, i. e., to the increase or decrease of the "active diameter" of the capillary tube.

Formulas 1-3 show that the radius of curvature of the capillary meniscus will be at a minimum when the meniscus is located in the Jamin capillary in the position shown in diagram I (R_1 in Fig. 5). At given magnitudes of angles θ and α the drop of the meniscus below the narrow area of the Jamin capillary may lead to a sharp increase in the curvature of the capillary meniscus and to a sharp increase in moisture tension in pores.[1]

Proceeding from the foregoing one may assume that during the evaporation of suspended moisture the capillary menisci of the upper soil layer gradually change to position I (Fig. 5), which is one of the reasons for the increase in moisture tension in pores near the evaporation front.

Received November 30, 1959

BIBLIOGRAPHY

1. ABRAMOVA, M. M. 1953. Movement of water in the soil during evaporation. Trudy Pochvennogo Instituta Akad. Nauk

---

[1] The case when the wetting angle is zero is an exception. In this case the radius of curvature of the capillary meniscus will be at a minimum when the meniscus is located in the narrow area of the Jamin capillary (Fig. 5, diagram III).

SSSR. Vol. 41.

2. ABRAMOVA, M. M., A. F. BOL'SHAKOV, N. S. ORESHKINA, and A. A. RODE. 1956. Evaporation of suspended moisture from the soil. Pochvovedeniye, No. 2.

3. BALAYEV, L. G. 1957. Certain problems in forecasting settling deformations of loess-like soils under irrigation channels. Author's summary of his dissertation. Moscow. Funds of the Moscow Institute of Water Economy Engineers im. V. R. Vil'yams.

4. BOL'SHAKOV, A. F. 1946. Forms of moisture movement in soils of the steppe group. Pochvovedeniye, No. 7.

5. BOL'SHAKOV, A. F. 1950. Water regime of dry-land soils in Uzbekistan. Trudy Pochvennogo Instituta Akad. Nauk SSSR. Vol. 32.

6. BUROV, D. I. 1952. Evaporation of water from fallow soil and soil under vegetation under conditions of the Trans-Volga region. Pochvovedeniye, No. 1.

7. VYSOTSKIY, G. N. 1934. Deep soil (full) in soil science. Pochvovedeniye, No. 6.

8. KORNEV, V. G. 1924. Suction force of the soil. Zhurnal opytnoy agronomii. Vol. 22. Leningrad.

9. LETUNOV, P. A., I. F. MUSYCHUK, and A. N. LAPSHINA. 1942. Movement of salts with capillary-suspended water. Collection in memory of V. R. Vil'yams. Moscow.

10. RODE, A. A. 1947. Water regime of soils in dry-land zone of the Uzbek SSR. Trudy Pochvennogo Instituta Akad. Nauk SSSR. Vol. 25.

11. RODE, A. A. 1952. Soil moisture. Izd. Akad. Nauk SSSR.

FREEZING AND THAWING OF SOIL UNDER VARIOUS TREATMENTS IN THE NORTH KAZAKHSTAN OBLAST'

V. YE. KAZAKOV and R. S. AYNIKEYEV, Kazakh State Agricultural Institute

The nature of the freezing and thawing of soil under conditions in Northern Kazakhstan is of extreme importance for obtaining a high yield of agricultural crops. The method of tillage and the sowing time are associated with the freezing depth and the nature of thawing of the soil. As we know, the spring in northern regions is cold and long as a rule. The soil thaws and warms slowly. A tremendous amount of solar heat, so necessary to the plants, is used on thawing it. As the soil thaws, its upper horizon loses more and more moisture and dries out. Under such conditions the seeds of spring wheat, which are sown early, fall on a cold soil, germinate slowly, and the seedlings are sparse and very weak. When sowing late there is always the danger that the seed will fall on a dry soil.

The problems of the freezing and thawing of the soil as related to air and soil temperature and also to soil moisture have been studied very little in the northern regions of Kazakhstan. No serious attempts have been made to substantiate scientifically sowing periods and to develop agricultural practices which would accelerate thawing and slow down the drying of the soil in spring.

We made our experimental studies (on the freezing and thawing of soil under various treatments) in the fields of the educational farm of the Petropavlovsk Technical School of the Mechanization of Agriculture. The soil is represented by ordinary clay loam chernozem, which is typical for the most part of the Northern Kazakhstan region.

The experiments were made in wheat stubble, sown after black fallow. Thus, the basic (autumn) soil tillage was performed under the second crop of wheat after black fallow. The following methods of tillage were studied as basic (autumn) tillage: 1) autumn plowing with a plow with a coulter to a depth of 20-22 cm; 2) autumn plowing without a moldboard to a depth of 30-35 cm, preceded by discing to a depth of 7-8 cm; and 3) autumn discing of stubble, twice, to a depth of 7-8 cm.

With these three systems of autumn tillage we studied several systems of seed-bed preparation: 1) early spring harrowing + presowing cultivation to a depth of 6-7 cm with harrowing; 2) early spring harrowing + presowing cultivation to a depth of 6-7 cm with harrowing and after-sowing rolling with a light roller; 3) early spring rolling with a heavy roller and harrowing + presowing cultivation to a depth of 6-7 cm with harrowing; and 4) early spring rolling with a heavy roller with harrowing and after-sowing rolling with a light roller.

The rolling was done with rollers filled with water, and light rolling with the rollers empty. Spring wheat of the variety Akmolinka 1 was sown with an ordinary drill seeder at a rate of 156 kg/ha (4 million seeds).

The area of each experimental plot was 1 ha; the experiments were not replicated. No measures for snow retention were taken.

The soil temperature was measured at 1 p. m. at depths of 5, 10, and 20 cm every 4 days. At the same time air temperature was measured at a height of 1.5 m. Soil moisture at depths of 0-10 cm, 10-20 cm, 30 cm, 50 cm, 70 cm, and 100 cm was determined during the same periods. The determinations were replicated 4 times.

The results of observations on the freezing and thawing of the soil depending on the method of basic (autumn) tillage are presented in Table 1.

The freezing depth was least in the soil which was disced and then plowed without a moldboard to a depth of 30-35 cm. The freezing depth in the soil plowed to a depth of 20-22 cm with a plow with a coulter was close to that in the foregoing soil. The greatest depth of freezing was observed in the soil disced twice in the autumn.

Soil thawing followed the same pattern. Thawing began after the disappearance of snow approximately between April 8 and 12. The soil that was plowed without a moldboard thawed most rapidly. Thawing of the soil plowed with a moldboard proceeded approximately as in the foregoing soil. Soil disced in the autumn thawed most slowly. In the first treatment of the experiment the soil was completely thawed by May 24, in the second treatment there was still a frozen layer of 1.7 cm at this time, and in the third treatment the soil thawed completely only by June 1.

Table 1

Depth of freezing and thawing of the soil, cm (average for 1957-1959)

Soil treatment	Freezing depth	Thawing depth						
		Apr. 12	Apr. 20	Apr. 28	May 8	May 16	May 24	June 1
Plowed with a plow with a coulter to a depth of 20-22 cm	160	12,3	40,3	59,6	90,0	135,3	158,3	160,0
Plowed without a moldboard to a depth of 30-35 cm and previously disced	146	13,6	51,0	77,6	96,4	141,0	146,0	—
Stubble disced twice to a depth of 7-8 cm	175	9,3	35,3	53,3	80,0	127,0	155,6	175,0

Note. Thawing was determined every 4 days, the data in the table are approximately for every 8 days.

Note: Comma represents decimal point.

Table 2

Air and soil temperatures in plots under various treatments (average for 1957-1959)

Observation date	Air temperature at 1 p. m., °C	Average soil temperature at a depth of 5-10 cm at 1 p. m., °C			Observation date	Air temperature at 1 p. m., °C	Average soil temperature at a depth of 5-10 cm at 1 p. m., °C		
		Plowed with a plow with a coulter to a depth of 20-22 cm	Plowed without a moldboard to a depth of 30-35 cm and prev. disced	Stubble disced twice to a depth of 7-8 cm			Plowed with a plow with a coulter to a depth of 20-22 cm	Plowed without a moldboard to a depth of 30-35 cm and prev. disced	Stubble disced twice to a depth of 7-8 cm
Apr. 12	2,4	0,7	0,7	0,6	May 24	26,4	15,1	15,6	15,0
Apr. 16	4,3	1,5	1,6	1,5	June 1	21,8	18,9	18,6	18,2
Apr. 20	0,5	0,8	1,0	0,8	June 10	28,4	22,9	22,1	22,3
Apr. 24	4,3	1,6	1,9	1,6	June 20	25,9	20,4	19,9	19,5
Apr. 28	2,8	1,5	1,6	1,5	June 30	22,0	19,9	19,3	18,9
May 4	16,0	7,3	7,6	7,4	July 15	22,3	19,8	19,3	19,3
May 8	21,5	10,2	10,5	10,0	July 30	18,2	15,7	14,9	15,2
May 12	12,4	7,9	8,3	7,9	Aug. 20	19,8	17,6	16,5	16,6
May 16	11,8	9,4	9,5	9,1					

Note: Comma represents decimal point.

The air temperature patterns at a height of 1.5 m and soil temperature patterns at a depth of 5-10 cm are shown in Table 2.

It must be noted that there was little difference between soil temperatures at a depth of 5-10 cm in the various treatments of the experiment. In spring the temperature of the air was considerably higher than that of the soil, while toward autumn this difference disappeared. The most important feature is that the soil temperature remained low throughout April and only by May 4 did it jump to 7.5°C and then rise gradually, sometimes dropping as a result of a drop in air temperature. These observations indicate that temperature conditions suitable for the sowing of spring wheat set in only by May 4. It is characteristic that the temperature jump occurred exactly from May 4-5. Thus in 1957 soil temperature was 2.2°C on April 28 and rose to 12.6°C on May 4. In 1958 the temperature of the soil was 0.9°C on April 28, 4.5°C on May 4, and rose to 10.2°C on May 8. In 1959 the temperature of the soil was 1.2°C on April 28 and rose to 4.7°C on May 4. Cold spells occur frequently after May 5-8 and the temperature drops for a certain period of time. Under the conditions of Northern Kazakhstan 25-30 days elapse between the time the snow disappears from the field and the time when more or less suitable temperatures for the sowing of spring wheat set in. During this long period the soil loses a considerable amount of water and its upper horizon sometimes dries out completely. This drying out is the real danger when sowing late, while early sowing on

Table 3

Soil moisture dynamics depending on the method of tillage in autumn (average for 1957-1959)

Determination date	Plowed with a plow with a coulter to a depth of 20-22 cm			Plowed without a moldboard to a depth of 30-35 cm and previously disced			Stubble disced twice to a depth of 7-8 cm		
	Moisture, % of the weight of dry soil, at depth of (cm)								
	0—10	0—50	0—70	0—10	0—50	0—70	0—10	0—50	0—70
Apr. 11	50,1	—	—	58,6	—	—	—	—	—
Apr. 15	52,4	—	—	56,3	—	—	50,6	—	—
Apr. 19	48,9	—	—	52,2	—	—	50,8	—	—
Apr. 23	41,2	33,9	—	45,3	38,7	—	43,5	—	—
Apr. 27	33,7	29,3	—	38,4	34,5	26,9	36,0	32,0	—
May 4	29,4	27,4	26,0	34,2	32,6	30,4	32,8	29,9	—
May 8	26,8	25,8	22,0	30,0	28,9	27,4	28,8	27,0	25,3
May 12	27,9	25,3	23,5	30,7	29,0	27,2	29,2	26,7	24,8
May 16	29,3	25,9	24,1	31,1	29,0	27,6	29,9	27,4	25,6
May 24	23,4	21,8	20,3	24,7	24,1	23,0	24,2	22,9	21,3
June 1	18,0	18,9	17,6	20,7	21,1	19,9	19,9	20,2	19,1
June 10	16,0	17,1	16,5	18,3	19,7	18,8	17,4	18,9	17,9
June 20	12,9	14,0	13,5	15,2	17,0	16,5	14,2	15,7	15,2
June 30	13,8	14,7	14,3	16,4	17,2	16,5	14,5	15,4	14,9
July 15	14,0	15,2	14,3	18,5	18,3	17,2	16,9	16,9	15,9
July 30	15,2	14,4	13,4	18,6	17,2	16,3	17,9	16,2	15,3
Aug. 20	18,2	16,8	15,2	20,0	18,4	17,6	17,3	17,9	16,7

Note: Comma represents decimal point.

cold soil reduces the crop yield.

The study of the dynamics of soil moisture in the same periods when the temperature and depth of thawing were measured gave the following results (Table 3).

Data in Table 3 show that from the moment the snow disappeared until May 4 when the soil temperature rose to 4-5°C, the moisture in the upper 10 cm of the soil decreased from 50%-58% to 29%-34% and continued to decrease in the following days, in spite of the spring harrowing of the stubble. Table 3 gives average data for 1957 (very dry), 1958 (medium), and 1959 (wet). In dry years the moisture content of the upper horizon decreases even more.

More moisture accumulated in the soil plowed without a moldboard to a depth of 30-35 cm in autumn than in the soil plowed in the autumn to a depth of 20-22 cm by the usual method with a plow with a coulter. Approximately the same amount of water accumulated in the soil disced twice in autumn as did in the foregoing soil, but as a result of much less evaporation from the disced soil its moisture content in summer exceeded that of the soil plowed with a moldboard.

In conformity with the moisture dynamics in the variously treated soils, the following yield of spring wheat was obtained (Table 4).

Data in Table 4 show that when the soil is prepared for the second sowing of wheat after black fallow autumn plowing with a plow with a coulter is very inferior to the other two methods of tillage, i. e., plowing without a moldboard preceded by discing, and discing of stubble twice. In the latter case the average grain yield in 3 years was only 0.6 cntr/ha lower than that obtained over soil plowed deeply without a moldboard, while at the same time the losses on tillage are much lower. Therefore one may limit oneself to surface tillage when sowing the second crop of wheat after black fallow.

However, against a background of basic (autumn) soil tillage a great role is played by the system of presowing cultivation, which is directed toward the maximum conservation of soil moisture.

Data on the yield of spring wheat and its dependence on the system of basic and presowing soil cultivation are presented in Table 5.

As can be seen from Table 5, heavy rolling and harrowing (in tandem) followed by presowing cultivation increases the grain yield by 46% as compared to early spring harrowing followed by presowing cultivation. Thus the yield increment in the plot plowed in autumn with a moldboard was 1.2 cntr/ha in 1957, 2.9 cntr/ha in 1958, and 3.0 cntr/ha in 1959. The increment in the plot plowed without a moldboard was 2.9 cntr/ha in 1957, 4.5 cntr/ha in 1958, and 3.6 cntr/ha in 1959. The only slightly negative results from rolling were obtained in 1957 on the plot disced twice in autumn, while in 1958 and 1959, after the stubble on this plot was rolled early with a heavy roller, the increment in yield was 2.8 and 1.1 cntr/ha, respectively.

Table 4

Yield of spring wheat sown at various periods depending on the method of soil tillage

Year	Grain yield, cntr/ha		
	Plowed with plow with a coulter to a depth of 20-22 cm	Plowed without a moldboard to a depth of 30-35 cm and prev. disced	Stubble disced twice to a depth of 7-8 cm
1957	4,5	7,6	6,4
1958	6,6	8,7	9,9
1959	5,6	7,5	5,7
Average	5,6	7,9	7,3

Note: Comma represents decimal point.

Table 5

Influence of basic and presowing soil tillage on the yield of spring wheat sown early (average for 1957-1959)

Presowing tillage	Autumn tillage		Stubble disced twice to a depth of 7-8 cm	Aver. grain yield for all tillage methods	
	Plowed with plow with a coulter to a depth of 20-22 cm	Plowed without a moldboard to a depth of 30-35 cm and prev. disced		In cntr/ha	In %
Harrowing of stubble twice plus presowing cultivation to a depth of 6-7 cm by harrowing, and sowing	3,9	5,4	6,2	5,2	100
Same, but with rolling after sowing	5,0[a]	7,1[a]	—	—	—
Rolling of stubble with a heavy roller and harrowing plus presowing cultiva. to a depth of 6-7 cm by harrowing, and sowing	6,3	9,1	7,4	7,6	146
Same, but with rolling after sowing	6.8	10,1	8,5	8,5	163

[a] Average of 2 years.

Note: Comma represents decimal point.

Good results were obtained from rolling after sowing with a light roller, both in the plot where stubble was harrowed in the early spring and then cultivated, and in the plot which was rolled in early spring with a heavy roller and harrowed and then cultivated and harrowed. The average increment in yield after after-sowing rolling was 17%-19%.

The positive results from rolling are attributable to the better retention of soil moisture because of decreased evaporation. The data in Table 6 confirm this opinion.

An increase in moisture from early spring rolling was observed in all soils tilled in autumn and was higher, the deeper the soil was tilled. This increase in rolled soil amounted in 3 years to an average of 1.5%-2% of the weight of dry soil, which in the layer from 0-70 cm was quite substantial. It should be noted that the moisture remained high in rolled plots throughout the summer.

Finally, let us discuss the problem of the sowing time of spring wheat in relation to soil thawing. It has been known for a long time that early sowings of spring wheat give lower yields under the conditions in Northern Kazakhstan than sowings at optimum periods. This results from the slow thawing and the comparatively low temperature of the soil, which slows down germination and weakens the seedlings. Such sowings are more contaminated by weeds than sowings in optimum periods. An idea about these relationships can be obtained from interrelation curves between air and soil temperatures and the dynamics of soil moisture

Table 6

Soil moisture dynamics in various plots with various basic and presowing tillage, % of dry soil weight in the layer from 0-70 cm (average for 1957-1959)

Observation date	Plowing with plow with coulter to a depth of 20-22 cm		Plowing without moldboard to a depth of 30-35 cm with previous harrowing		Stubble discing twice to a depth of 6-7 cm	
	Stubble harrowing plus presowing cultivation	Rolling with a heavy roller and harrowing plus presowing cultivation	Stubble harrowing plus presowing cultivation	Rolling with a heavy roller and harrowing plus presowing cultiv.	Stubble harrowing plus presowing cultivation	Rolling with a heavy roller and harrowing plus presowing cultivation
May 4	27,9	28,5	30,7	31,5	32,2	34,3
May 8	23,7	24,8	27,4	28,4	25,5	26,2
May 12	23,3	24,8	27,0	28,1	25,1	25,7
May 16	24,1	25,3	27,2	28,7	28,2	28,0
May 24	20,4	21,4	22,6	24,3	21,1	22,2
June 1	17,7	18,6	19,7	20,4	19,2	20,0
June 10	16,7	17,4	18,8	19,4	18,1	19,1
June 20	14,2	15,1	16,8	17,4	15,9	17,0
June 30	15,8	16,6	17,4	17,8	16,6	17,1
July 15	15,6	16,8	17,7	18,2	16,7	17,4
July 30	14,3	14,8	16,3	16,9	15,8	16,3
Aug. 20	15,4	16,2	17,5	18,0	17,1	17,7
Average	19,1	20,0	21,5	22,6	20,9	21,8

Note: Comma represents decimal point.

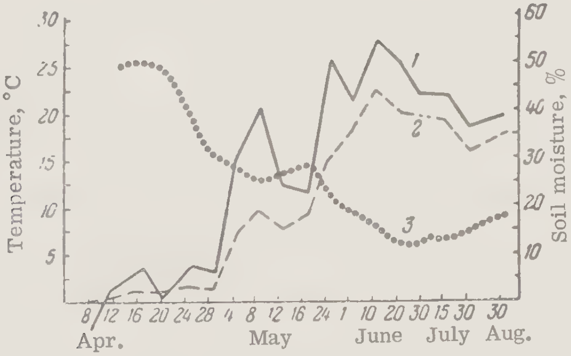

Fig. 1. - Interrelationship between the air temperature, that of ordinary chernozem and its moisture dynamics (average of 3 years from 1957-1959)
1 - air temperature at 1 p.m.; 2 - soil temperature at a depth of 5-10 cm at 1 p.m.; 3 - soil moisture in the layer 0-10 cm.

(Fig. 1).

The grain yields of spring wheat under such soil and air temperature conditions and moisture conditions in the upper soil layer present the following picture. When sown on May 18, when the soil temperature was between 9-10°C (and was not lower but increased), the grain yield in all rolled experimental plots was 2-2.5 times higher than when sowing was done on May 9. When sown on May 18, seedlings appeared after 8 days; while when sowing was done on May 9 the seedlings appeared 13 days later. They were weaker and more sparse. Therefore, wheat sowing in optimum periods, which usually set in between May 10-12, in the Northern Kazakhstan region, is fully substantiated from the scientific point of view. But the optimum period for sowing is very short, only about 8 days, and therefore sowing should be done in the shortest period possible from May 10-12 to 18-20. A further delay in the sowing of spring wheat is hazardous for the yield.

Conclusions

1. Under conditions of the Northern Kazakhstan Oblast' the depth of soil freezing reaches 150-180 cm and greatly depends on the autumn cultivation of the soil. The minimum depth of freezing was observed in soil plowed deeply without a moldboard in autumn. The maximum depth of freezing was recorded in a plot where the stubble was disced twice in autumn.

2. Soil thawing in the spring lasts 20-25 days. It proceeded most rapidly in soil deeply plowed without a moldboard in autumn and least rapidly in the plot where the stubble was disced in autumn.

3. The soil thaws very slowly and the upper horizons of the soil remain cold for a long time. The soil thaws completely by May 25-30. According to temperature conditions the optimum period for the sowing of spring wheat sets in about May 10-12 and lasts to May 18-20.

4. The soil accumulates more moisture when it is plowed deeply without a moldboard in autumn than it does when it is plowed with a moldboard. When the stubble is disced in autumn under the second crop of wheat after black fallow the soil accumulates as much moisture as it does when it is plowed in the autumn with a plow with a coulter, and evaporates less in the summer; therefore, the amount of water in disced soil is smaller only as compared to that in soil deeply plowed without a moldboard.

5. The wheat yield was considerably higher in the plot where stubble was disced in the autumn and that which was deeply plowed without a moldboard than that in the plot plowed with a moldboard with a plow with a coulter; therefore, when preparing soil for the second wheat crop after black fallow it is not necessary to plow the soil in autumn with a plow with a coulter or to plow it deeply without a moldboard; it is sufficient to disc the stubble twice, or to stir the soil with a shallow moldboard plow.

6. The rolling of the fall-plowed stubble field with a heavy roller followed by harrows, instead of harrowing twice in early spring, increases the wheat grain yield by an average of 35%-40%, while after-sowing rolling with a light roller increases the yield by another 15%-18%. Therefore the system of soil tillage prior to sowing involving early-spring rolling with a heavy roller coupled with harrows, the cultivation of the soil with harrows (in combination) to a depth of 6-7 cm, and rolling after sowing with a light roller (also coupled) must be subjected to large-scale commercial tests in fields plowed in the fall and those plowed deeply without a moldboard.

Received June 11, 1959

USE OF THE RADIOACTIVE ISOTOPE P^{32} IN STUDYING PHOSPHORIC ACID MOVEMENT IN THICK CHERNOZEM

P. P. LEVENETS, V. V. Dokuchayev Agricultural Institute, Khar'kov

The investigations by a number of authors showed that because of the intense adsorption of the phosphate ion by soil, the phosphorus from superphosphate becomes fixed primarily in that layer of the soil to which superphosphate is applied, and moves only a short distance.

The weak movement of phosphorus from superphosphate in chernozems was demonstrated by the investigations of Kostychev (7), Sazanov (1), Yegorov (6), Maslova (8), and Avdonin and Milovidova (2). Avdonin and Milovidova (2) found that the rate of phosphorous movement in chernozems considerably increases as the soil moisture increases. According to their data, phosphorus moved 2.5-3 cm under conditions of a constant moisture of 60% of the capillary moisture capacity, and more than 14 cm with ample irrigation.

In conducting experiments on thick chernozem in 1922, Yegorov (6) found that almost all the soluble compounds of superphosphate, applied to a depth of 8-10 cm, had moved into the upper soil layers after 18 days, forming efflorescenses of phosphoric acid salts.

From the experiments of Avdonin (1) and others it was established that plants are most sensitive to an increase in the concentration of fertilizers in their first stage of growth. At the same time Avdonin (1) found that the majority of agricultural plants take up non-readily available phosphates with more difficulty in the first stage of their growth than in the later stages.

It was established in recent years (3, 4, 5, 9, 10, 12 and others) that corn is especially sensitive to an increased concentration of fertilizers and takes up only little of non-readily available phosphates. Therefore it became necessary to determine the best place to apply fertilizers locally under various soil and climatic conditions when sowing corn and other agricultural crops in order to increase the nutrition of young plants and not to create a harmful concentration for the seedlings. The solution of this problem depends on the biological characteristics of the plants and the rate with which nutrients from fertilizers diffuse in the soil.

The use of the radioactive phosphorous isotope P^{32} makes it possible to determine more accurately (as compared with other methods) the rate of phosphorous movement from superphosphate in the soil and its uptake by plants.

We conducted our investigations in the thick chernozem of the "Kommunist" sovkhoz, Khar'kov rayon, in 1958 and 1959. Fertilizer, consisting of 2 g of ordinary superphosphate containing 60 microcuries of the radioactive phosphorous isotope P^{32}, where applied in spots. The diffusion rate of phosphorus was studied in corn fields. Superphosphate containing the radioactive phosphorous isotope P^{32} was applied in one instance at a distance of 5 cm from and 2 cm deeper than the corn seeds, and in another instance, 5 cm below the corn seeds. In the first case the depth to which the fertilizer was applied was 10 cm, and in the second case, 13 cm.

After applying the fertilizer, the rate of phosphorous movement from the superphosphate in the soil and the time and intensity of its uptake by corn plants were determined.

The determinations were based on the radiation intensity of the radioactive P^{32} phosphorus in soil samples taken at various distances from the spots to which the fertilizer was applied and at various depths.

The radioactivity of the soil was measured directly in the field by means of a tagged atom intensity meter (IMA instrument) with a "Tula" battery. The results of the measurements showed that when applied in spots before sowing corn, the phosphorus from superphosphate moved slowly in a horizontal direction and faster toward the surface of the soil. The movement of phosphorus in the soil was most intense the first days after the application of the superphosphate. Measurements made 15 days after the fertilizer was applied to the soil showed no further movement of the radioactive phosphorous isotope.

The content of superphosphate phosphorus in milligrams per 100 g of soil was calculated from data for P^{32} decay counts. When tagged superphosphate was applied to a depth of 13 cm, a "strong" radioactive radiation was observed over a radius up to 5 cm. More than 90% of the P_2O_5 in superphosphate concentrated in this area. "Moderate" radiation was observed at a distance from 5-10 cm, where 6% of the

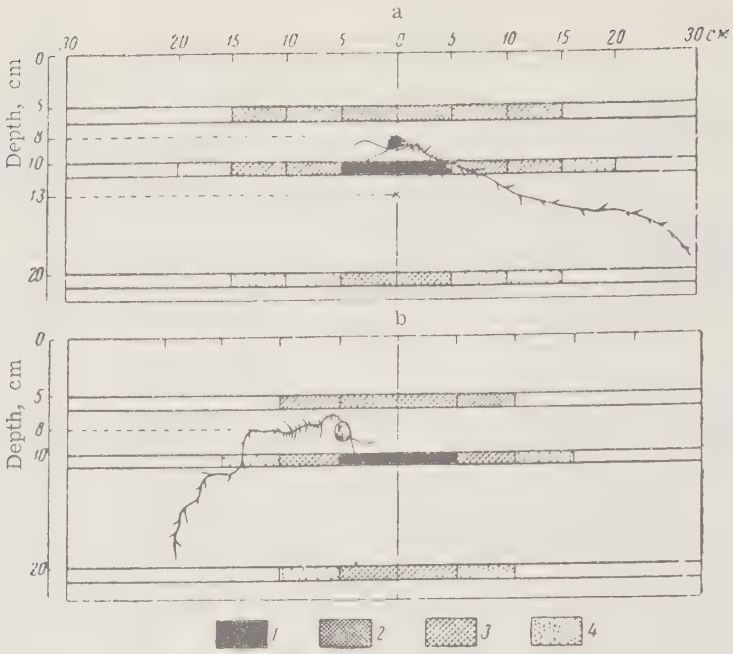

Fig. 1. - Diffusion of radioactive phosphorous in superphosphate 15 days after applying to soil.
A - superphosphate applied 5 cm below the seeds; B - superphosphate applied at a distance of 5 cm from and 2 cm deeper than the seeds. Radioactive radiation: 1 - "strong" - more than 6 mg of P_2O_5 in superphosphate per 100 g of soil; 2 - "moderate," from 2-6 mg; 3 - "weak," from 0.5-2 mg; 4 - "very weak," less than 0.5 mg; x - application site of the superphosphate.

P_2O_5 in superphosphate penetrated, and only an insignificant amount of phosphorus moved beyond a distance of 10 cm from the spot to which the fertilizer was applied.

The results of radioactive radiation measurements showed that radioactive phosphorus moved very slowly in dry weather (1 cm/day). Phosphorus moved much more rapidly during precipitation.

In comparing Figure 1-A and -B one can see that the diffusion rate of phosphorus in the soil changed with a difference of only 3 cm in the depth of application of tagged superphosphate. When the tagged superphosphate was applied to the soil at a depth of 10 cm, the distribution radius of phosphate was noticeably smaller than when the superphosphate was applied at a depth of 13 cm. The data show the leading role of moisture in the distribution of phosphorus in the soil.

In addition to field experiments we studied the distribution rate of phosphorus from superphosphate in the soil in the laboratory to exclude the influence of weather conditions. The soil sample studied was an average sample from the upper horizon of thick chernozem. The soil was placed in clean glass tubes 30 cm long and 4 cm in diameter. Two grams of superphosphate containing 60 microcuries of radioactive phosphorus were applied to one end of the tube with soil. Altogether six tubes were used: three were filled with non-sterilized soil, while the rest were filled with soil sterilized at 110°C for 6 hours. Moreover, sterile conditions were kept in the tubes: the soil was wetted with boiled water and the tubes were sealed with sterile cotton. The soil was sterilized to determine the role of microorganisms in the movement of phosphorus. At the beginning of the experiment soil moisture was 40% of total moisture capacity and 12 days later it was brought to 80%.

The movement rate of phosphorus in the soil was also determined with the tagged atom intensity meter, whereby the threshold of intensified counts, caused by the radiation of the radioactive phosphorous isotope P^{32}, was recorded. The results (Table 1) showed that the diffusion rate of phosphorus was practically the same in both the sterilized and the non-sterilized soils.

At low soil moisture (40% of total moisture capacity) phosphorus moved 1 cm from the spot it was applied to in the first day, 2 cm in the next 3 days, and then movement practically ceased. Twelve days after the beginning of the experiment soil moisture was brought to 80% of total moisture capacity, whereby the distribution rate of phosphorus sharply increased to 1 cm/day in the first 7 days, and then began to slow down.

Table 1

Diffusion of phosphoric acid from a site of superphosphate in glass tubes with thick chernozem

Moisture content in % of total moisture capacity		40			80			
Number of days from fertilizer application to the count measurements		1	3	9	13	20	26	29
Phosphorous diffusion, in cm, from the spot where fertilizers were applied to the soil	Without sterilization	1	3	3	4	11	13	13
	With sterilization	1	3	3	5	9	12	12

Field and laboratory data showed that at low moisture phosphorus is sorbed near the spot it is applied to and can be taken up when individual granules come in contact with the roots. Under such conditions it is very important how the places where superphosphate is applied are arranged relative to the seeds. The selection of such a place is less important when soil moisture is high and phosphorus is capable of greater movement so that it reaches the roots more rapidly.

To determine the best place for the application of superphosphate, we investigated the time and intensity of the nutrient uptake by corn plants in the field. To this end we set up a special experiment in 1958 by applying superphosphate containing the phosphorous isotope P^{32} to corn according to the following scheme:

1. Without fertilizer (control).
2. Fertilizer was applied together with the seeds.
3. Fertilizer was applied at one side of the seeds at a distance of 5 cm and 2 cm deeper than the seeds.
4. Fertilizer was applied 5 cm below the seeds.
5. Fertilizer was applied 15 cm below the seeds.
6. Fertilizer was applied 25 cm below the seeds.

The radioactive phosphorus (50 millicuries of P^{32}) was added to each hole with 2 g of superphosphate powder.

The radioactivity of individual plant parts was measured periodically after the corn seedlings appeared. The first three measurements were made with the tagged atom intensity meter, the remaining three were made with the B-2 device with a face counter. The results of the measurements are given in Table 2.

The phosphorous content was determined by the exchangeable molybdenum method (precipitation by the Lorenz method and further determined by the Nissen method). The tagged phosphorus taken up by corn plants from the superphosphate was calculated from the decay count of the radioactive phosphorus in samples taken from the corn leaves.

It follows from Table 2 that in the first 2-3

Table 2

Uptake of phosphorous fertilizer by corn plants with various placements of tagged superphosphate. Phosphorous (P_2O_5) content, % of dry weight of corn leaves

Experimental treatment No.	Place of application of tagged superphosphate to corn before sowing	Number of days from germination to the counting									
		5		8		13		19		28	
		Total	Tagged	Total	Tagged	Total	Tagged	Total	Tagged	Total	Tagged
1	Without fertilizer	0,48	—	0,52	—	0,46	—	0,42	—	0,38	—
2	Into holes with the seeds	0,58	0,23	0,56	0,21	0,51	0,24	0,48	0,24	0,43	0,26
3	5 cm from and 2 cm deeper than the seeds	0,49	—	0,52	—	0,48	—	0,43	0,02	0,39	0,20
4	5 cm below the seeds	0,52	0,05	0,55	0,05	0,49	0,24	0,47	0,19	0,44	0,2
5	15 cm below the seeds	0,47	—	0,53	—	0,47	0,01	0,45	0,04	0,41	0,2
6	25 cm below the seeds	0,49	—	0,52	—	0,48	0,09	0,45	0,03	0,40	0,1

Note: Comma represents decimal point.

weeks phosphorus was taken up by plants from the superphosphate with a great intensity only where the fertilizer had been applied together with the seeds or below them. After 2-3 weeks phosphorus began to be taken up with almost the same intensity by the corn plants in all the treatments of the experiment. At this time the corn plants developed a secondary root system.

When superphosphate was applied together with the seeds, the great concentration of the soil solution slowed down plant growth in the first stage of their life, so that the plant weight was somewhat lower than that of the control. The plant leaves in this treatment of the experiment had the highest phosphorous content in their first stage of life, which apparently had an unfavorable effect on the growth of corn.

The highest growth was obtained when superphosphate was applied 5 cm below the seeds. Apparently in this case there was a more favorable concentration of available phosphorus at the right time as compared to the other treatments of the experiment, which is attributable on the one hand to a better contact between the phosphorus and the new rootlets by which the corn plants feed during their first days of growth, and on the other hand, to the more rapid movement of phosphorus toward the seeds.

Thus, when superphosphate is applied below the corn seed, primary roots are more able to reach the superphosphate than when it is applied on the side of the seeds.

Conclusions

1. The radius of phosphorous movement from superphosphate is limited to 2-3 cm in thick chernozem at low soil moisture (about 40% of total moisture capacity). At high soil moisture (about 80% of total moisture capacity), the movement of the phosphorus increases considerably (up to 10-15 cm in the first 2 weeks). When superphosphate is applied at a distance of 5 cm from the seeds, phosphorus is taken up only by occasional corn plants, the primary roots of which happen to come into contact with the fertilizer (about 20% of the plants), until a secondary root system forms; when superphosphate is applied 5 cm below the seeds, the fertilizer can penetrate to the roots of all plants and can be taken up by them.

2. In field experiments phosphorus from superphosphate was taken up with great intensity during the first 2-3 weeks only by corn plants in the experiments where the fertilizer was applied together with the seeds and 5 cm below the seeds. Somewhat later phosphorus began to be taken up by plants from the fertilizer applied 15 and 25 cm below the seeds.

3. After the formation of a secondary root system, phosphorus began to be taken up by the corn plants with the same intensity in all experimental treatments.

Received October 12, 1959

BIBLIOGRAPHY

1. AVDONIN, N. S. 1957. Achievements of Soviet agricultural chemistry in 40 years. Udobreniye i urozhay. No. 10.
2. AVDONIN, N. S. and YE. P. MILOVIDOVA. 1954. Interrelationship between granulated fertilizers and the soil. Vestnik Moskovskogo universiteta. No. 3.
3. ARTYUKHOV, I. K. and V. I. ZOLOTOV. 1954. Application of fertilizers during square-nest sowing. Zemledeliye. No. 5.
4. VLASIUK, P. P. and A. M. GROZDINSKIY. 1958. Characteristics of the phosphorous uptake from superphosphate by corn. Nauchnyye trudy Instituta fiziologii rasteniy. Vol. 15.
5. GULYAKIN, I. V. and G. M. SMIRNOV. Uptake of superphosphate by corn during its first stage of growth. Udobreniye i urozhay. No. 1.
6. YEGOROV, M. A. 1923. Clarification of the causes of the uneven distribution of P_2O_5 along the soil profile. Sel'kokhozyaystvennoye opytnoye delo. No. 4.
7. KOSTYCHEV, P. A. 1898. Tillage and fertilization of chernozem. Collection of articles.
8. MASLOVA, A. L. 1935. Technique of fertilizer application. Collection of articles. Izd. VIUAA im. K. K. Gedroytsa. Moscow-Leningrad.
9. NAYDIN, P. G. 1956. Fertilization of corn. Udobreniye i urozhay. No. 1.
10. OZEROV, V. I. 1957. Growth of the root system of corn in relation to the method of fertilizer application. Udobreniye i urozhay. No. 4.
11. SAZANOV, V. I. 1916. Phosphorous fertilizers and the root system of sugar beets. Trudy Sumskoy sel'skokhozyaystvennoy opytnoy stantsii. No. 10. Sumy.
12. TYULIN, V. A. and T. B. BEUS. 1956. Fertilization of corn. Kukuruza. No. 1.

CHANGE IN HUMUS COMPOSITION IN THE ANNUAL CYCLE OF SOD-PODZOLIC SANDY LOAM SOIL

A. V. BARANOVSKAYA, Central Soil Science Museum, Academy of Sciences, USSR

The study of the dynamics of the group composition of soil humus is of great interest. It allows one to determine under what conditions the formation of the fraction of humic substances occurs and how the physicochemical properties of soils change with it. It had already been noted by Kostychev (7) that the cohesion of chernozem soils decreases after they dry out, that they acquire a "fluffy" structure, becoming less stable; after prolonged wetting the coherence of the soil is restored.

We observed a considerable increase in the solubility of humic substances in samples of ordinary chernozem, taken in the early spring from the Kamennaya Steppe, Voronezh Oblast' and also samples of dark-chestnut soils, taken after fields were irrigated, when treating them directly with a 0.1 N alkaline solution, as compared to samples of the same soils taken during a dry period.

Investigations specially devoted to the study of the seasonal changes in the composition of humus in sod-podzolic, bog, gray forest, and chernozem soils and soils of more southern groups have been appearing lately (1, 2, 5, 8, 11). These investigations show that the group and fractional composition of humus change considerably during the growing period. Thus, the total content of humic acids in sod-podzolic-gley clay loams, of the Leningrad Oblast' somewhat decreases in summer, while it increases in the autumn, whereby the increase is preceded by an increase in the amount of fulvic acids (5). The mineralization of humic substances predominates in soils of more southerly regions during prolonged drying, while humus accumulates during colder and wetter periods. However, the problems of the rate of these processes and their role in the dynamics of soil fertility have not been studied enough.

The seasonal changes in the composition of soil humus were studied by us when making permanent soil investigations at the scientific-experiment station of the Botanical Institute in the Priozerskiy rayon of the Leningrad Oblast' in 1958 and 1959.

Soil samples were taken from experimental plots under 1- and 2-year old timothy, 2-year old clover, and in black fallow. The plots were established on sod slightly podzolic, gravelly-sandy loam with a two-layered profile, developed on a gentle slope leading to Lake Otradnenskiy. The results of determinations of the particle-size and chemical composition of this soil are given in Table 1.

As may be seen from the results of total chemical analysis, the soil studied is characterized by slight podzolization, in spite of its acid reaction and its lack of base saturation. This is evidenced by the absence of removal of sesquioxides and alkali earth bases from the upper horizons. The sharp change in the total chemical composition from a depth of 40 cm is attributable to the two-layered structure of the soil-forming parent material. The fact that the coarse gravelly sandy loam is underlain at a shallow depth by varved clay determines the temporary excessive wetting of soil during the spring-autumn period, in spite of the fact that it is found on a southern slope.

To study the group composition of humus, we took soil samples from 4 points in each plot from a depth from 0-10 cm and immediately mixed and passed them through a sieve with 1 mm diameter openings. Part of a sample was analyzed under natural moist conditions, and the other part, in an air-dry state. The composition of humus was analyzed by the Tyurin method (10), as modified by Ponomareva (9).

In order to judge of the applicability of the given method to the study of the seasonal changes in the composition of soil humus, we present data on the magnitudes of variations in the content of various fractions of humic substances for three parallel samples taken from pot experiments. The pots were filled with soil from the plowed layer taken from one of the fallow plots in the autumn of 1957.

The data in Table 2 show that the fluctuations in the content of humic acids are relatively small in all fractions. The fluctuations in the amount of fulvic acids in groups I and Ia are greater. As a result of this, the seasonal dynamics of the amount of fulvic acids in these fractions is less reliable than the changes of the other fractions of soil humus.

Before we examine the results of the study of the dynamics of the group composition of soil humus, let us briefly describe the weather conditions during the years of our observations.

Table 1

Results of total chemical, particle-size, and chemical analyses of sod slightly podzolic, sandy loam. Profile 56.

Total composition

Horizon	Depth, cm	Ignition loss, %	In percent of ignited soil								
			SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	SO_3	Sum of fractions
A plowed	0—10	4,47	80,00	11,10	2,54	0,31	0,19	1,70	0,69	0,62	97,15
"	10—20	4,22	80,10	10,65	2,69	0,30	0,18	1,63	0,70	0,41	96,70
B_1	25—35	1,77	80,50	10,68	2,08	0,20	0,12	1,54	0,55	0,24	95,91
B_2	40—50	5,78	68,50	16,10	6,41	0,90	0,22	1,77	2,18	0,32	96,30
BC	55—65	6,57	65,30	17,20	7,30	1,05	0,22	1,86	2,60	0,17	95,70
C	80—90	5,86	67,50	16,70	6,27	1,02	0,27	2,10	2,20	0,28	95,34

Particle-size analysis by the pipette method

Horizon	Depth, cm	% coarse particles	Pre-treatment loss, %	In 100 parts of fine earths						Sum of particles <0.01 mm in diameter
				1—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	
	0—10	5,9	1,3	51,3	28,4	7,9	3,0	5,7	2,5	11,2
B_2	40—50	None	2,0	4,1	7,7	28,2	11,4	21,0	25,6	58,0
BC	55—65	"	2,7	2,1	5,7	25,1	13,2	24,0	27,3	64,4

Chemical indices and humus contents

Horizon	Depth, cm	pH		Hydrolytic acidity	Sum of exchangeable cations	% saturation	P_2O_5, mg/100g	Total		Ratio between carbon and nitrogen, C:N
		Water	Salt	in meq				Humus	Nitrog.	
								B%		
A	0—10	5,6	4,5	3,9	3,3	45	10,0	2,40	0,105	13
A	10—20	5,5	4,4	4,7	2,7	38	10,0	3,00	0,07	24
A	20—30	5,8	4,5	3,4	1,7	34	12,5	1,40	0,04	20
B_1	30—40	5,9	4,5	2,3	1,7	28	15,0	0,60	Not determined	--
B_2	40—50	None		3,0	13,2	82	15,0	0,55		--
BC	50—60	"		Not det'd		--	Not det'd	0,50		--

[a] Humus content in the 0-100-cm layer -- 105 metric tons/ha.

Note: Comma represents decimal point.

In the spring of 1958 the snow disappeared from the experimental plots by the end of April. May was wet and cold, warming up only in the last week; June was cool and rainy. The hot and dry weather at the beginning of July changed as early as in the first week to rains; sudden cooling took place, which was followed by hot weather at the end of the month. August was warmer than July, but rains began at its end and again cooling set in. September was dry and comparatively warm, even though night frosts occurred in mid-September. The growth of plants in 1958 was intense in spite of the cool weather and lasted until October. The winter of 1958-1959 was snowy and comparatively warm. The soil was not frozen by March 1959. The spring of 1959 was agreeable and early, the snow disappeared in the first half of April and the soil began to dry rapidly. May was cool and dry; the beginning of June was very warm, but there were thunderstorms and it became cooler in mid-June. After the rains ceased, very hot and dry weather set in in early July which persisted until August 25. Then drizzles set in and it became cooler. As a result of the drought in July and August the plants bloomed early in 1959 and the growth practically ceased.

The results of the seasonal composition of soil humus are given in Table 3. As may be seen from these data, the content of humic acids, directly entering the alkaline extract, was rather high (35%-37% in the composition of humus) during the wet and cold spring and in the beginning of the summer of 1958 in soil under

Table 2

Limits of variations in the content of various fractions of humic substances in slightly podzolic, sandy loam sod soils[a]

Pot No.	% Moisture	% total carbon	Humic acids				Fulvic acids					Substances hydrolyzable in 1-n H_2SO_4	Sum of hydrolyzable substances
			Ia	I	II		0	Ia	I	II	Total		
I	18,2	1,18	27,8	2,0	1,8	31,6	5,4	17,5	5,7	9,1	37,7	10,4	79,7
II	15,6	1,19	27.6	3,9	1,0	32,5	5,9	14,5	3,2	11,0	34,6	10,6	77,7
III	18,8	1,20	25,7	3,0	1,6	30,3	5,7	8,1	10,7	9,7	34,0	10,6	74,9

[a] The soil samples were taken from 3 growth-experiment pots, filled with soil from a depth of 0-15 cm, from the first fallow plot with grass seedlings in September 1957.

Note: Comma represents decimal point.

intensely growing timothy (sown in August 1957). It decreased somewhat in summer and fractions of humic acids, more strongly fixed to the mineral part of the soil, appeared; their quantity increased greatly in September after the warm and moderately humid weather, which apparently promoted the fixation of humic acids. The total content of substances from the fulvic acid group varied less than the total content of humic acids. In 1958 the amount of fulvic acids increased somewhat from spring to mid-summer, dropped by the end of July, and increased again toward autumn, changing in a direction opposite to that of the humic acid content.

The dynamics of the content of humic acids in the soil under black fallow was of the same nature in 1958 as that under timothy. At the end of October, after frosts set in, the content of easily available humic acids in the soil decreased. It decreased even more by January 1959, amounting to 20% of total carbon in the soil under timothy, and only to 14% in the soil under black fallow. However, in March 1959 the content of easily available humic acids in soil again increased greatly. As was already mentioned, the soil was thawed at this time under 50-60 cm of snow. From the data obtained one may conclude that changes in the humic state of the soil continue even in winter.

During the warm and dry spring of 1959, the content of easily available humic acids of group I was considerably lower than during the wet and cool spring of 1958. The summer drought had comparatively little effect on the change in the group composition of humus, which generally was subjected to less considerable changes during the growing period of 1959 than it was in 1958.

Under 2-year clover, where the composition of humus was studied only in 1959, the content of humic acids in soil was similar to that under timothy and in black fallow. The content of free fulvic acids in the soil (fractions separated under direct treatment of the soil with 0.1 N H_2SO_4) varied widely in 1958 and 1959, reaching a maximum in the soil under black fallow in September 1958 and at the end of August 1959.

Considerable changes occurred also in other fulvic acid fractions, but their total content in the composition of humus in 1958 changed to a lesser degree than the content of humic acids. An increase in the content of the group of fulvic acids sometimes preceded a certain increase in the content of humic acids, a fact which had already been noted for podzolic soils (5).

The second fraction of fulvic acids (entering the alkaline extract after the decalcification of the soil) was often absent, or comprised a considerable part of the humus. However, the content of this fraction in the composition of humus in all soils studied was found to have increased in March 1959. It also reached considerable values in the summer and autumn of 1959, both under clover and under timothy.

The content of the third fraction of fulvic acids (the most strongly bound to the mineral portion of the soil and entering the alkaline extract only after acid hydrolysis) did not vary too greatly, but did not exceed 2%-11% in the composition of humus.

However, changes in the total content of fulvic acids during the various periods of observation in 1958 were quite considerable and sometimes took place very rapidly: for instance, the ratio between individual fulvic acid fractions and their total content in soils under clover changed noticeably in July 1959 during several rainy days as a result of the increase of the zero and II fractions of fulvic acids.

Noticeable seasonal fluctuations were also found in the content of the non-hydrolyzable residue of humic substances (determined by difference). In winter, when the soil was freezing, the humic substances in it became fixed. During dry periods the amount of non-hydrolyzable residue also increased slightly, while during periods with high soil moisture, when the solubility of humic substances increased, the content of non-hydrolyzable residue decreased. During the prolonged drought in the summer of 1959, the group composition of humus changed comparatively little, even though the total content of humus during this period decreased slightly at all points of observation, including those in

Table 3

Seasonal dynamics of humus composition from 1958-1959 under herbage and in fallow—samples with natural moisture

Date	Soil moisture, %	Total organic carbon, %	Total organic carbon, %											
			Humic acids				Fulvic acids					Substances hydrolyzable in 1-N H_2SO_4	Sum of hydrolyzable substances	Non-hydrolyzable res. (by diffr.)
			I	II	III	Total	0	1	II	III	Total			
1-year old timothy, 1958														
May 23	22,0	1,81	35,6	1,9	Not det'd.	37,5	10,3	11,3	0,0	Not det'd.	21,6	Not det'd.	—	—
June 21	12,5	1,57	37,2	0,2	"	37,4	6,4	20,4	0,0	"	26,8	"	—	—
July 4	7,5	1,63	24,0	3,3	4,6	31,9	3,4	23,6	0,0	3,8	31,8	7,7	70,4	29,6
Aug. 29	10,6	1,44	33,5	0,0	4,5	38,0	5,4	13,9	3,3	2,5	24,8	Not det'd.	—	—
Aug. 16	12,0	1,80	25,0	0,0	4,8	29,8	3,9	14,5	8,4	2,9	29,7	10,6	70,1	29,9
Sept. 11	11,8	1,65	26,8	11,0	6,5	43,3	7,1	9,8	0,0	10,8	27,7	Not det'd.	—	—
Oct. 29	21,2	1,72	23,6	0,0	2,2	25,8	5,0	10,9	9,3	6,1	31,3	8,4	65,5	34,5
Black fallow														
July 4	8,5	1,73	20,0	8,4	5,2	33,6	4,5	19,3	0,0	Not det'd	—	10,3	—	—
July 19	12,1	1,60	27,4	5,0	5,1	37,6	3,6	22,0	0,0	5,1	30,9	Not det'd.	—	—
Aug. 16	10,6	1,83	27,4	0,0	3,0	30,4	4,7	14,2	10,2	2,8	31,9	10,8	73,1	26,9
Sept. 11	10,4	1,65	24,2	17,6	9,7	51,5	15,5	5,5	0,0	11,9	31,9	Not det'd.	—	—
Oct. 29	19,8	1,72	23,6	0,0	2,2	25,8	5,0	10,9	9,3	6,1	31,3	8,4	65,5	34,5
2-year old timothy, 1959														
Jan. 16	20,0	1,45	20,2	6,0	6,5	32,7	5,3	17,0	Not det'd.	5,4	27,7	10,30	—	—
Mar. 19	17,0	1,77	28,0	0,0	8,0	36,0	4,7	5,3	22,4	3,7	34,1	8,4	78,5	21,5
Apr. 24	19,5	1,85	24,0	0,0	0,0	24,0	5,5	14,8	0,0	7,9	28,2	10,6	62,8	37,2
June 8	12,3	1,70	23,1	1,0	5,7	29,8	4,9	15,5	7,3	9,3	37,0	7,5	74,3	25,7
June 19	6,1	1,55	25,6	1,5	4,4	31,5	5,0	18,8	0,0	6,0	25,5	11,8	68,8	31,2
July 2	11,9	1,78	20,3	7,5	6,85	34,65	3,4	15,1	2,5	6,3	27,3	12,05	74,0	26,0
July 6	10,7	1,76	25,0	2,2	6,10	33,0	7,7	8,5	4,4	4,35	24,95	6,8	65,05	34,95
Aug. 12	3,7	1,60	26,2	3,8	3,8	33,8	3,4	9,3	4,2	3,5	21,4	6,95	62,15	37,85
Aug. 29	10,5	1,46	25,0	0,0	6,35	31,35	2,4	21,1	0,0	4,3	27,8	4,50	63,70	36,30
Nov. 4	15,2	1,63	26,5	4,1	5,4	37,00	3,8	20,4	0,0	6,0	30.2	9,10	76,1	23,90
2-year old clover														
Mar. 19	14,7	1,70	26,6	2,0	5,7	34,30	4,9	5,2	13,2	4,1	27,4	7,3	69,00	31,00
June 8	12,0	1,70	23,2	3,0	4,95	30,95	4,2	19,0	1,7	10,5	35,4	9,8	76,15	23,85
June 19	4,40	1,65	26,2	0,4	6,0	31.60	4,2	17,6	0,0	3,5	21,8	10,7	64,10	35,9

June 2	10,3	1,85	21,2	4,5	5,96	31,65	2,4	14,5	0,0	5,3	22,2	11,3	65,15	34,85
July 6	11,2	1,79	28,1	1,5	5,90	35,50	7,1	5,5	14,7	9,45	30,75	7,0	73,25	26,75
Aug. 12	4,60	1,50	28,3	4,6	4,40	37,3	4,8	8,7	7,9	5,0	26,4	9,4	73,40	26,60
Aug. 29	11,7	1,61	23,6	0,0	6,70	30,3	3,4	16,7	3,2	4,5	27,8	4,55	62,65	37,35
Nov. 4	13,3	1,57	24,0	6,4	5,5	35,9	3,5	17,9	0,0	6,2	27,6	10,0	73,5	26,5
Black fallow														
Jan. 16	20,4	1,95	14,0	8,7	6,4	29,1	6,5	9,3	Not det'd.	2,2	—	10,9	—	—
Mar. 19	18,7	2,00	26,3	0,0	6,0	32,3	4,4	4,0	16,7	3,5	28,6	7,3	68,2	31,8
Apr. 24	20,2	1,80	24,5	0,0	0,0	24,5	6,2	14,4	0,0	8,2	28,8	14,1	67,4	32,6
June 8	14,3	1,88	21,8	3,2	4,7	29,7	4,3	15,1	0,0	10,3	29,7	9,2	68,6	31,4
July 2	11,5	1,78	22,9	6,7	6,6	35,2	2,6	15,1	0,0	5,1	22,8	11,7	69,7	30,3
Aug. 12	6,3	1,77	22,6	3,7	4,1	30,4	3,3	15,9	2,2	4,7	26,1	8,3	64,8	35,2
Aug. 29	10,3	1,41	25,0	4,7	7,55	37,25	17,2	2,9	6,5	9.7	36,3	7,75	81,30	18,7

Table 4

Seasonal changes of the fractional composition of organic matter (air-dry samples)

Sample No.	Date of sampling	Total carbon %	In % of total carbon											
			Humic acids				Fulvic acids					Substances hydrolyzable in 1-N H_2SO_4	Sum of hydrolyzable substances	Non-hydrolyzable res. (by differ.)
			I	II	III	Total	0	I	II	III	Total			
Timothy	May 5, 1958	1,81	25,9	0,0	3,6	29,5	10,8	5,0	0,2	3,9	19,9	8,6	58,0	42,0
	May 21	1,65	24,0	0,9	5,6	31,5	3,9	20,0	0,0	4,2	28,2	8,5	58,2	31,8
	June 21	1,57	25,2	0,0	8,8	34,0	3,5	15,8	11,3	10,4	41,0	13,2	87,2	12,8
	July 4	1,63	20,7	3,8	4,1	28,6	3,7	17,3	4,4	16,8	42,6	14,5	85,7	14,3
	July 29	1,44	26,8	4,3	3,8	34,9	4,6	15,7	2,5	5,2	28,0	8,2	71,1	28,9
	Aug. 16	1,80	29,4	0,0	5,7	34,7	9,2	17,1	9,2	2,0	22,1	8,0	64,8	35,2
	Sept. 11	1,65	27,1	2,8	2,9	32,8	2,3	16,0	0,0	5,8	24,2	5,0	62,0	38,0
	Oct. 29	1,72	19,7	3,9	4,9	28,5	10,2	13,1	4,8	1,4	29,5	7,1	65,1	34,9
	Jan. 16, 1959	1,45	27,1	0,0	4,4	31,5	4,2	18,5	4,5	6,6	33,5	10,5	75,5	24,5
Fallow	July 4, 1958	1,73	22,3	0,0	6,3	28,6	2,9	15,3	1,4	3,3	22,9	10,3	61,8	38.2
	Aug. 16	1,83	21,1	5,9	5,25	32,25	3,35	13,15	0,85	4,45	21,8	11,2	65,0	35,0
	Sept. 11	1,65	25,2	0,0	6,2	31,4	5,8	15,5	0,0	2,3	23,6	20,8	65,8	34,2
	Oct. 29	1,72	23,2	6,5	1,8	31,5	5,2	16,0	0,0	9,3	30,5	5,2	67,4	32,6
	Jan. 16	1,97	23,5	0,0	4,45	27,95	3,9	11,8	3,7	2,15	21,45	8,0	57,4	42,6

Note: Comma represents decimal point.

black fallow.

In order to find out what changes occur in the composition of humus when the soil is brought to an air-dry state, we analyzed the same soil samples after they had been dried. The results of the investigations are given in Table 4.

When comparing the results of the study of the composition of humus in naturally moist and dry samples, it must first of all be noted that the observed differences are the greater, the greater the soil moisture is when the samples are taken. The increase in the amount of humic acids in soils after drying, noted by Kashchenko (5), was found by us only in those samples which were taken in August and in late autumn and winter. On the contrary, the drying of samples taken in spring and summer, and also in September, when the solubility of humic substances was high, slightly reduced the solubility of humic acids and increased the content of non-hydrolyzable residue. This can be explained by the aging of colloids during drying and their transition to a less soluble state.

However, a noticeable increase in the mobility of humic acids during the drying of the soil was found in samples taken after the soil had frozen. Apparently soil freezing changes the dispersion of soil colloids and promotes a certain fixation of humic acids. Thus, the filtration of extracts from fresh samples of frozen soils was slower and the precipitation of colloids in alkaline extracts by sodium sulfate was reached with more difficulty.

In order to judge changes in the degree of dispersion of humic acids, we determined the threshold of coagulation of humic acids separated after the decalcification of the soil by the method described by Kononova and Bel'chikova (6). The results obtained are given in Table 5. It was found that humic acids from samples taken at the end of October have the highest degree of dispersion, judging by their resistance to precipitation by electrolytes. They did not coagulate even with the addition of large amounts of electrolyte (25 meq $CaCl_2$ per 1 liter of humate). Humic acids extracted from soil samples taken in September 1958 were characterized by a great capacity to precipitation by electrolytes and, consequently, by a lower degree of dispersion. Humic acids from samples taken at the end of July 1958 had the lowest coagulation threshold. This points to the fact that during the summer of 1958 the humic acids extracted from the soils were characterized by a lower dispersion and, consequently, a more complicated structure, and a higher condensation of the aromatic nucleus than during the autumn, when they apparently formed anew.

Conclusions

1. Considerable seasonal changes in the content of individual fractions of humic and fulvic acids were found in a sod slightly podzolic sandy loam in plots under 1- and 2-year old timothy, 2-year old clover, and black fallow.

2. The highest content of humic acids and fulvic acids of group I was found in early spring and summer when soil moisture was high. It decreased noticeably in the late autumn of 1958 and in the winter of 1959 after the soil had frozen and increased again in March 1959 when the soil thawed. During the comparatively dry spring and summer of 1959, the changes in the group composition of humus were less considerable.

3. The fluctuations in the content of humic substances of group I were more pronounced in fallow than under timothy. This is apparently related to the sharper changes in temperature conditions in the soil under black fallow, where

Table 5

Variations of the coagulation threshold of humic acids of the first group, extracted from samples of the plowed layer of sod slightly podzolic soil

Plots	Date of sampling	Beginning of coagulation		Partial coagulation		Total coagulation		Notes
		Time, hours	$CaCl_2$, meq/1 liter of humate	Time, hours	$CaCl_2$, meq/1 liter of humate	Time, hours	$CaCl_2$, meq/1 liter of humate	
Timothy	July 29, 1958	Immed	14	1	14	24	6	Complete coagulation
Fallow	July 29, 1958	"	10	»	10	24	6	Same
Timothy	Nov. 11, 1958	1	20	24	10	48	10	There is no complete coagulation
Fallow	Oct. 29, 1958	Absent		48	20	Absent		Slightly turbid
"	" "	"	"	1	25	48	16	Partial coagulation
Timothy	Mar. 19, 1959	Immed.	20	»	14	24	20	Almost complete coagulation
Fallow	Mar. 19, 1959	"	20	»	14	24	20	Same

the soil temperature during the day was 3-5°C higher than in plots under vegetation.

4. Seasonal changes in the composition of humus in air-dry samples were less pronounced than in natural moist samples.

5. Humic acids extracted from samples taken in the autumn of 1958, when they apparently formed anew, were very resistant to precipitation by electrolytes and, consequently had the highest degree of dispersion.

Humic acids, extracted from samples taken at the end of July 1958, when an increase of the degree of condensation of their aromatic nucleus could have occurred, had the lowest threshold of coagulation.

6. Judging by the data obtained, one may assume that the variability in the composition of humus in the soils studied is associated to a high degree with the seasonal changes in the properties of organic soil colloids, particularly humic acids, the dispersion of which increases during periods of high soil moisture and decreases when the soil dries out.

Received December 7, 1959

BIBLIOGRAPHY

1. ALEKSANDROVA, L. N., O. A. NAYDENOVA, and M. F. SHUMAKOVA. 1956. Dynamics of the group and fractional composition of humus in the annual cycle of soil formation in sod-podzolic soils. Zapiski Leningradskogo Sel'skokhozyaystvennogo Instituta. No. 11.
2. ALIYEV, S. A. 1958. Conditions of the accumulation of humus in the major soil groups of Azerbaydzhan. Izv. Akad. Nauk SSSR, seriya biologicheskaya. No. 1.
3. BARANOVSKAYA, A. V. 1954. Study of organic matter in the chernozems of Kamennaya Steppe. Sbornik rabot Tsentral'nogo muzeya pochvovedeniya Akademii Nauk SSSR. No. 1.
4. BARANOVSKAYA, A. V. 1957. Problem of the influence of irrigation on the composition and supply of humus in soils. Sbornik rabot Tsentral'nogo nuzeya pochvovedeniya Akad. Nauk SSSR. No. 2.
5. KASHCHENKO, A. S. 1958. Dynamics of the group composition of humus in sod-podzolic soil. Zapiski Leningradskogo Sel'skokhozyaystvennogo Instituta. No. 13.
6. KONONOVA, M. M. 1951. Problem of soil humus and contemporary objectives of its study. Izd. Akad. Nauk SSSR.
7. KOSTYCHEV, P. A. 1898. Origin of the major groups of soil and their characterization from the physical, chemical, and biological point of view. Sbornik Sel'skoye i lesnoye khozyaystvo Rossii.
8. NIKOLAYEVA, T. A. 1958. Seasonal dynamics of the composition of organic matter in drained and cultivated bog soils. Pochvovedeniye, No. 12.
9. PONOMAREVA, V. V. 1957. Method of studying the composition of humus according to the I. V. Tyurin scheme. Pochvovedeniye, No. 8.
10. TYURIN, I. V. 1951. Method of analysis for the comparative study of the composition of soil humus. Trudy Pochvennogo Instituta im. V. V. Dokuchayeva Akad. Nauk SSSR. Vol. 38.
11. KHARITONOVA, YE. P. 1958. Influence of forest shelterbelts on the composition of humus in gray soils of the forest steppe and its change with time. Trudy Obshchestva estestvoispytaniya pri Kazanskom universitete. Vol. 2.

INFLUENCE OF PROLONGED, SYSTEMATIC APPLICATION OF FERTILIZERS ON HUMUS ACCUMULATION IN SOIL, AND THE AGRICULTURAL CROP YIELDS

N. G. GORODNIY, Ukrainian Academy of Agricultural Sciences

The role of humus in soil is very diversified. It determines the potential fertility of soil and at the same time is one of its more mobile parts. The growing of agricultural crops and the use of organic and mineral fertilizers have a great effect on the variations in the amount of humus in soil (2, 3, 4, 6, 7, 8, 9, 11, 12, 13).

We studied the influence of organic and mineral fertilizers and their mixtures, depending on the duration of application, on soil humus under permanent hemp and a rotation with row crops, clover, perennial legume-grass mixtures, and pure fallow. The studies were made on dark-gray, slightly podzolized clay loam in the fields of the All-Union Scientific-Research Institute for Bast Culture (city of Glukhov, Sumy Region).

When the experiment was started in 1931 the characteristics of the soil were: a pH of 6.65 of the water extract, a pH of 6.12 of the salt extract, a hydrolytic acidity of 3.77 meq exchangeable bases of 17.64 meq/100 g of soil, a base saturation of 82.5%, a humus content of 3.70%, total nitrogen of 0.22%, available phosphorus (according to Kirsanov) of 11.9 mg/100 g of soil, and available potassium of 4.95 mg/100 g of soil.

Samples for humus determination were taken with the Izmail'skiy auger. The humus content was determined by the Tyurin method. The results of analyses are given in Table 1.

As can be seen from the data, the amount of soil humus under hemp left unfertilized for 27 years did not change during this period, while in the area where manure was applied at a rate of 40 metric tons/ha, the humus content increased by 1.39%, and when NPK was applied at a rate equivalent to 40 metric tons of manure, it increased by 0.09%.

The humus content in the soil increased with increasing amounts of manure and hardly changed with increased amounts of mineral fertilizers. Thus in the plot with permanent hemp to which 20 metric tons/ha of manure were applied and where the total amount of manure applied in 19 years was 380 metric tons/ha, the humus content was 0.94% higher than in the non-fertilized control area. A double amount of manure, 640 metric tons/ha in 16 years, increased the content of humus in the soil by 0.45%, i. e., almost by 50% more than in the area where manure was applied at a rate of 20 metric tons/ha. However, when the rate of manure application was raised to 80 metric tons/ha, the humus content in the soil increased only by 0.08% as compared to the area to which 40 metric tons/ha were applied.

The application of various amounts of mineral fertilizers had almost no effect on the accumulation of humus in the soil. Thus when $N_{120}P_{90}$-K_{90} and $N_{200}P_{100}K_{240}$ were applied, the content of humus in the soil increased only by 0.11%-0.09% as compared to that in the soil of the control area.

Thus, the prolonged, systematic application of manure to hemp promoted the accumulation of humus in the soil, while the application of mineral fertilizers under the permanent crop did not produce any change in the humus content of the soil, a fact which is corroborated by the investigations of Bel'chikova (1), and Gusev (5) on a typical sierozem under old irrigation under continuous cotton.

If one compares the increments of humus on manured plots with the amount of manure applied during the whole period of the experiment, one finds that about 70%-86% of the organic matter in manure has mineralized and only about 14%-30% turned to humus (Table 2).

As the amount of manure applied to the soil is increased, the mineralization of organic matter also increases, while the relative accumulation of humus in the soil decreases. Thus when 380 metric tons/ha of manure (95 metric tons/ha of organic matter) were applied in our experiment, the amount of humus in the soil increased by 29.2 metric tons/ha, or 30.7% of the organic matter added to the soil, while when 3 times more manure was applied (1280 metric tons/ha), the amount of humus in the soil increased only by 44.1 metric tons/ha, or 1.5 times more, and was 13.7% of the total amount of organic matter added.

The high mineralization of organic matter on strongly manured plots is attributable to the intensification of microbiological activity (Table 3).

As the data show, the amount of all physiologi-

Table 1

Influence of various amounts of fertilizer on the accumulation of humus in soil

Experimental version	Amount of fertilizer used, metric tons/ha	Humus in % after 27-year continuous hemp	
		Total	Increment
Without fertil.	0	3,74	—
Man. 20 met. t/ha	380	4,68	0,94
" 40 "	640	5,13	1,39
" 80 "	1280	5,21	1,47
$N_{120}P_{90}K_{90}$	25,0	3,85	0,11
$N_{200}P_{100}K_{240}$	37,0	3,83	0,09

Note: Comma represents decimal point.

Table 2

Accumulation of humus in the soil depending on the amount of manure used

Treatment	Applied		Accumulation of humus in soil under manure applic.		Residual organic matter in manure, %
	Man. fr. the beginning of the experiment	Organic matter with manure	% of that in the control	metric tons/ha	
	Metric tons/ha				
Manure, 20 metric tons/ha	380	95	0,94	29,2	30,7
" 40	640	160	1,39	41,7	26,0
" 80	1280	320	1,47	44,1	13,7

Note: Comma represents decimal point.

Table 3

Influence of fertilizers on the change in the microflora of soil, million per 1 g of soil

Treatment	Number of physiological groups of microorganisms	Including anaerobic denitrifyers
Without fertilizers	659	215
Manure, 20 met. t/ha	620	294
" 40 "	1161	654
NPK, equivalent to 40 met. tons of manure	380	97
$N_{120}P_{90}K_{90}$	649	66

al groups of microorganisms in 1 g of soil almost doubled in the area where 40 metric tons/a of manure were applied as compared to the ontrol area, while the number of anaerobic enitrifying microorganisms increased almost times. Where NPK was applied at a rate quilvalent to 40 metric tons of manure, the umber of physiological groups of microorganisms and of anaerobic denitrifying organisms increased 3 and 7 times, respectively.

The prolonged application of physiologically acid fertilizers, such as ammonium sulfate or nitrate, superphosphate, and potassium chloride, suppresses microbiological processes and leads to a decrease in the number of microorganisms in the soil.

The humus content in the soil is affected not only by the amount of fertilizer applied, but also on the duration of application (Table 4).

According to data in Table 4, the 16 applications of 40 metric tons/ha of manure increased the humus content in the soil by 0.33% as compared by the 2 applications of the same amount of manure. The prolonged application of NPK in an amount equivalent to 40 metric tons/ha decreased the humus content in the soil. When $N_{200}P_{100}K_{240}$ was applied 16 times, the humus content in the soil decreased by 0.79% as compared to the 2 applications of the same amount of mineral fertilizer.

The humus content in the soil was higher after an application of 40 metric tons/ha of manure than it was after an application of NPK at a rate equal to 40 metric tons of manure; when

Table 4

Influence of the duration of fertilizer application on humus accumulation in soil, %

Treatment	Fertilizers applied		
	2 times	16 times	Humus increment
Manure, 40 met. t/ha	4,80	5,13	+0,33
NPK, equivalent to 40 met. tons of man.	4,62	3,83	—0,79

Note: Comma represents decimal point.

Table 5

Influence of fertilizers on humus accumulation in various soil layers, %

Depth, cm	Without fertilizers	Manure, 80 metric tons/ha	$N_{200}P_{100}K_{240}$
0—20	3,92	5,29	3,84
20—30	3,76	—	3,41
30—40	2,22	4,02	2,91
40—50	1,94	3,18	2,20
50—60	1,75	2,92	1,73
60—70	1,23	2,50	1,40
70—80	1,06	2,47	1,21

Note: Comma represents decimal point.

applied twice it was 0.18% higher and when applied 16 times, 1.30% higher.

These data indicate that the prolonged application of manure to hemp must be considered not only as a means of providing plants with nutrients, but also as a means of enriching the soil with humus.

Our layer-by-layer determinations of the humus content in the soil showed that the influence of fertilizers on the change in its content is not limited only to the plowed horizon, but it also affects the deeper soil layers (Table 5).

Under prolonged application of manure, the humus content increased both in the plowed layer and in the deeper layers. Thus, when a total of 1120 metric tons/ha of manure (at a rate of 80 metric tons/ha) where applied to a continuous cropping of hemp, the amount of humus increased throughout the entire soil profile to a depth of 80 cm. The decrease in the humus content under the application of mineral fertilizers was limited only to the plowed layer (0.30 cm), according to data in Table 5.

Judging by our data, the negative effect of mineral fertilizers on the accumulation of humus in soil is attributable to the considerable decrease in the base saturation of the soil, and also to the increase in soil acidity under the influence of physiological acid mineral fertilizers. We also studied the effect of the simultaneous application of manure, mineral fertilizers, and lime on the humus content in the soil (Table 6).

As may be seen from Table 6, the increase in the humus content in the soil was almost the same when 20 metric tons/ha of manure were applied with $N_{60}P_{45}K_{45}$ and when N_{60} was added annually to an application of 80 metric tons/ha to continuous cropping of hemp, as when only manure was applied.

A single application of 3.3 metric tons/ha of lime annually for 16 years to the area manured at a rate of 40 metric tons/ha promoted the fixation of organic substances in the soil. The amount of humus in the soil of this plot was 0.20% higher than without lime. These data fully confirm the conclusions of Kostychev (6) that lime intensifies the decay of fresh plant residues and inhibits their decomposition in the later stages of humification. A single application of lime at a rate of 4.3 metric tons/ha against a background of mineral fertilizers leads to a decrease of humus in the plowed layer by 0.48% and by 0.56% in the sub-plowed layer as compared to the area where $N_{120}P_{90}K_{90}$ was applied without lime.

Thus, the application of potassium and magnesium, even in small amounts, against a background of mineral fertilizers intensified the decomposition of humus in the soil.

The importance of calcium in the decomposition of organic substances in the soil depends primarily on the reaction of the medium, as pointed out by Sokolovskiy (10). The addition of $CaCO_3$ to acid soil intensifies the decomposition of organic matter, however an excess of lime inhibits it. Kononova (7) pointed out that lime acts in different directions: on the one hand it intensifies the decomposition of readily available organic substances, and on the other hand it changes part of the decay products into a more stable form, this change being accompanied by the formation of cyclic compounds.

According to the results of our long-term experiments made on dark-gray, slightly pod-

Table 6

Influence of manure, mineral fertilizers, and lime on the humus content in the soil, %

Treatments	Depth, cm		Treatments	Depth, cm	
	0–25	25–40		0–25	25–40
Manure, 20 metric tons/ha	4,08	3,38	Manure, 40 metric tons/ha	4,05	2,32
" 20 " "	4,11	3,00	" 40 " + 3.3 met. t/ha lim	4,25	2,90
" 80 " "	4,65	2,90	$N_{120}P_{90}K_{90}$.	3,85	3,17
" 80 " "	4,66	3,53	$N_{120}P_{90}K_{90}$ + 4.3 met. t/ha of lime	3,37	2,51
$N_{60}P_{45}K_{45}$	3,72	2,55	$N_{200}P_{100}K_{240}$	3,95	3,53
$N_{60}P_{45}K_{45}$ + 20 met. t/ha of manure	3,76	2,90	$N_{200}P_{100}K_{240}$ + 1.8 cntr/ha of CaMg	3,50	2,84

Note: Comma represents decimal point.

Table 7

Influence of manure and perennial herbs on humus accumulation in soil, %

Treatment	Continuous hemp	Perennial herbs	Pure fallow
Without fertilizers	4,37	4,43	4,13
Manure, 40 metric tons/ha	4,76	5,13	4,86
" 80 " "	5,27	5,14	5,03
$N_{120}P_{90}K_{90}$	4,27	4,25	3,84
$N_{60}P_{45}K_{45}$	3,98	4,46	—
20 met. t/ha of man. + $N_{60}P_{45}K_{45}$	4,63	5,10	4,70

Note: Comma represents decimal point.

zolic clay loam (Table 7) and experiments conducted at the experimental field of the Moscow Agricultural Academy im. K. A. Timiryazev on podzolic soil and at the Sumy experiment station on slightly leached chernozem, in addition to manure, a favorable influence is exerted on the accumulation of humus in the soil by clover and perennial legume-grass mixtures.

The application of manure both to continuous hemp, crop rotation with perennial herbs, and fallow row-crop rotation, has a favorable influence on the accumulation of humus in the soil. As the amount of manure is increased, the percent of humus in the soil increases.

With the same amounts of manure, the accumulation of humus in the soil is greater in crop rotation with perennial herbs than in tilled fallow or continuous hemp. In areas which had not been fertilized for 20 years, the highest amount of humus (4.45%) was found under crop rotation using perennial legume-grass mixtures, and the least (4.13%) under fallow row-crop rotation.

The prolonged, systematic application of mineral fertilizers to hemp lead to a decreased amount of humus in the soil both under the continuous hemp and under fallow row-crop rotation. The humus content in the soil against a background of mineral fertilizers remained the same only under perennial legume-grass mixtures.

According to the data of Shkonde (14) the amount of humus in the soil increased by 0.45% as compared to the control plot at the Sumy experiment station as a result of a 10-year application of manure to a plot under beets and pure fallow rotation; the application of the same amount of manure to clover increased the humus content by 0.65%.

The determination of total carbon and the carbon in hydrolyzates showed that the richer the soil is in organic matter the more of it is transformed into hydrolyzate (Table 8). The amount of cellulose and hemicellulose in the soil varied in the various experimental plots parallel with changes in the total content of carbon, increasing under the application of manure, and decreasing under the application of mineral fertilizers.

Table 9 gives the analysis of water extracts from the soil.

The data in this table show that the prolonged application of mineral fertilizers sharply increases the amount of substances in the soil entering the water extract.

The dried and ignited residue in the water extract from the soil with a background of

Table 8

Content of organic carbon in soil

Treatments	Fertilizers applied						
	Once			5 times			19 times
	Total carbon in % of soil weight	Hydrolyzed carbon, % of total carbon	Cellulose and hemi-cellulose carbon, %	Total carbon in % of soil weight	Hydrolyzed carbon, % of total carbon	Cellulose carbon, %	Total carbon in % of soil weight
Without fertilizers	2,51	0,56	0,27	2,64	0,56	0,30	2,53
Man. 20 met. t/ha	2,69	0,54	0,30	2,83	0,59	0,32	2,76
" 40 "	2,78	0,54	0,32	3,18	0,64	0,36	—
" 80 "	3,00	0,59	0,35	3,55	0,68	0,45	3,05
$N_{200}P_{100}K_{240}$	2,68	0,52	0,29	2,46	0,54	0,28	2,42
$N_{120}P_{90}K_{90}$	2,59	0,51	0,29	2,53	0,51	0,29	2,25

Note: Comma represents decimal points.

Table 9

Analysis of water extracts in percent of soil weight

Treatment	Dry residue		SiO_2	Al_2O_3+ +Fe_2O_3	CaO	Water-soluble humus in mg 0.05 N $KMnO_4$ per 100 g of soil
	Dried	Ignited				
Without fertilizers	0,0631	0,0492	0,0078	Trace	0,0097	32,35
Manure, 40 metric t/ha	0,1076	0,0595	0,0149	"	0,0135	66,95
NPK, equivalent to 40 metric t/ha of manure	0,3008	0,1770	0,0268	0,0005	0,0327	69,00

Note: Comma represents decimal point.

mineral fertilizers is four times higher as compared to the soil in the non-fertilized plot and almost three times higher than in the manured soil. The amount of water-soluble humus in soil with a background of mineral fertilizers is twice as high as in the control, and is even somewhat higher than when manure is applied at a rate of 40 metric tons/ha. The increase of SiO_2, R_2O_3, and CaO, as well as of water-soluble humus in the water extract, points to noticeable changes taking place in the adsorption complex of the soil under the influence of mineral fertilizers.

The intensification of the decomposition of soil humus under the application of mineral fertilizers and under continuous cropping of the same agricultural crops was noted by a number of investigators. Thus, Waksmann (2) points out that it is possible that the humus decomposes in the soil under the influence of mineral fertilizers and that its decomposition is the faster the higher the ratio is between carbon and nitrogen. According to the data of the American investigators Salter and Grenn (15), the amount of organic carbon in the soil decreased by 60% after growing winter wheat without using fertilizers for 30 years, and almost by 50% under corn with inter-row cultivation. According to the data of Konova (7), the decrease of humus may reach 40%-60% of its total supply in the soil in individual cases under long-standing fallow.

Let us examine yield data. The prolonged and systematic application of fertilizers affected not only the yield of agricultural crops, but also their quality.

A 27-year cropping to hemp was accompanied annually by increased yield. The average yield of hemp straw in 27 years was 13.5 cntr/ha, while its average yield in the first 6 years was 9.7 cntr/ha. The constancy of the yield of hemp straw under its continuous cropping without fertilizer in the first years and its considerable increase in the following years is attributable to the fact that agricultural practices have been improved systematically when hemp was grown. Thus, the initial plowing at the beginning of the experiment was done to a depth of 18 cm and since 1937 changed to a depth of 22 cm which was found to be more effective for the growing of hemp. Since 1952 the less pro-

Table 10

Influence of the prolonged use of fertilizers on the yield of continuous cropping to hemp

Treatments	Straw				Grain			
	1931—1936		1931—1957		1931—1936		1931—1957	
	cntr/ha	%	cntr/ha	%	cntr/ha	%	cntr/ha	%
Without fertilizers	9,7	100	13,5	100	3,63	100	2,65	100
Manure, 20 metric tons/ha	22,9	236	29,2	216	6,43	177	5,43	205
" 40 " "	29,0	300	39,8	295	7,29	200	6,38	241
" 80 " "	32,8	338	43,9	325	9,38	259	7,32	276
$N_{60}P_{45}K_{45}$	18,8	198	22,3	165	6,58	182	4,55	171
$N_{120}P_{90}K_{90}$	23,3	239	30,1	223	9,36	257	6,89	260
$N_{200}P_{100}K_{240}$, equivalent to 40 met. tons of manure per ha	26,4	272	33,9	251	9,38	270	7,14	269

Note: Comma represents decimal point.

ductive varieties of Central Russian hemp were replaced by the more productive southern varieties, which were harvested for buttons.

The prolonged application of manure and mineral fertilizers promoted the increase in the yield of hemp fiber and seed (Table 10).

The yield of hemp straw increased with increasing amounts and duration of the application of manure and mineral fertilizers. It increased on the average in 27 years (Table 10), as compared to the control, by 116% in plots manured at a rate of 20 metric tons/ha, by 195% in plots manured at a rate of 40 metric tons/ha, by 225% in plots manured at a rate of 80 metric tons/ha, and by 65% in plots fertilized with $N_{60}P_{45}K_{45}$, by 123% in plots fertilized with $N_{120}P_{90}K_{90}$, and by 151% in plots fertilized with $N_{200}P_{100}K_{240}$.

When an optimum amount of manure was used (40 metric tons/ha) and mineral $N_{200}P_{100}K_{240}$ fertilizers were applied at a rate equal to 40 metric tons/ha, the yield of hemp straw was higher after manure. It must be noted that mineral fertilizers containing nitrogen give a higher yield in the first years than those containing manure. The decrease in the yield of hemp straw against a background of mineral fertilizers applied at a rate equal to 40 metric tons of manure takes place after the fourth to sixth year.

The yield of fiber in cntr/ha during the first 2 years was higher after mineral fertilizers, while in the following years it was higher after manure. The strength and count of fiber was

Table 11

Yield of hemp fiber against various backgrounds of fertilizers and preceding crops, cntr/ha (15-fold application of fertilizers)

Treatments	Continuous hemp		Pure fallow		Perennial grasses	
	Long fiber	Total	Long fiber	Total	Long fiber	Total
Without fertilizers	1,7	2,9	7,2	9,3	4,0	4,7
Lime, 5.4 metric tons/ha	1,4	2,5	7,3	9,4	4,4	5,9
Manure, 40 metric tons/ha	6,6	10,4	7,7	13,1	8,3	11,4
Man., 40 met. t/ha + 3.3 met. t/ha lime	7,0	9,3	7,2	11,7	6,8	10,4
$N_{120}P_{90}K_{90}$	4,9	7,2	8,5	12,1	7,0	9,2
$N_{120}P_{90}K_{90}$ + 4.3 met. t/ha of lime	6,1	8,7	7,4	11,9	7,1	9,8
$N_{200}P_{100}K_{240}$	5,3	8,0	9,0	12,8	7,4	9,8
$N_{200}P_{100}K_{240}$ + 3.6 met. t/ha of Ca, Mg	6,0	8,1	8,1	12,4	7,0	9,9
Manure, 20 metric tons/ha	5,0	6,8	9,7	12,9	7,4	9,9
" 20 " t/ha + $N_{60}P_{45}K_{45}$	6,5	9,2	6,8	11,2	7,0	9,3
Manure 80 metric tons/ha	6,8	9,8	7,9	13,4	8,2	12,5
" 80 " "	7,4	10,0	6,9	12,9	7,0	11,2
$N_{60}P_{45}K_{45}$	4,8	6,5	7,7	10,2	6,2	7,9
$N_{60}P_{45}K_{45}$ + 20 metric tons/ha of lime	5,7	7,8	8,3	11,1	7,0	9,0

Note: Comma represents decimal point.

higher after manure than after mineral fertilizers.

Our experiment allows us to compare the effect of the prolonged application of organic and mineral fertilizers to continuous cropping of hemp, to alternating crops of hemp, clover, and potatoes, to perennial grasses, and to pure fallow. The effect of fallow row-crop rotation and clover on the yield of hemp straw is insignificant without fertilizers. However, the stems of hemp after all preceding crops without fertilization did not exceed 55-60 cm and were suitable only for the production of short fibers. The prolonged application of manure and mineral fertilizers increases the yield of hemp two times after all preceding crops.

When applying the same amounts of manure and mineral fertilizers, the yield during the first years is higher with the mineral fertilizers and only later does the indisputable advantage of manure manifest itself. The advantage of manure in comparison with NPK is shown with seeding hemp after hemp in the fourth to sixth year, seeding hemp after row-crop in the sixth to eighth year, and seeding after perennial grass sod in the tenth to eleventh year.

Pure fallow has a considerably greater advantage over the other predecessors of hemp when fertilizers are applied for a long time. In our experiment, the yield of hemp straw after non-fertilized pure fallow was 52.3 cntr/ha, or 33 cntr/ha more than continuous cropping to hemp, and 17.1% more than perennial grass sod. Pure fallow was favorable for the yield of hemp straw in all experimental treatments, independent of the amount of fertilizer used of the preceding crops. Crops preceding hemp have a considerable influence on its yield and on the quality of the fiber (Table 11).

The seeding of hemp after pure fallow and after perennial grass sod without fertilization resulted in a fiber yield from 5.7-9.3 cntr/ha, or 2 to 3 times higher than that of continuous cropping to hemp.

The highest yield of long fiber was obtained on pure fallow when 20 metric tons/ha of manure were applied to it after perennial grass, when 40 metric tons/ha were applied to it, and in continuous hemp, when 80 metric tons/ha were applied to it.

The application of lime against a non-fertilized background had little effect on the yield of long and total fiber after all the predecessor crops studied. The addition of 20 metric tons/ha against a long-standing background of mineral fertilizers was very effective and resulted in an increase in the yield of fiber. It must be noted that the count and strength of the long hemp fiber after pure fallow and perennial grasses were considerably higher than when hemp was grown continuously. The introduction of fallow and perennial legume-grass mixtures into the hemp crop rotation had a positive effect on the yield of hemp and increased its quality.

The prolonged, systematic application of fertilizers to hemp was also reflected in the yield of other crops used in the hemp crop rotation. Thus in 1937, after 2 years of manuring, the yield of potato increased by: 50 cntr/ha with the application of 20 metric tons/ha of manure; 60 cntr/ha with the application of 40 metric tons/ha of manure, and 127 cntr/ha with the application of 80 metric tons/ha of manure. After a 7-year application of manure the increase in potato yield was: 86 cntr/ha with the application of 20 metric tons/ha of manure; 120 cntr/ha, with the application of 40 metric tons/ha of manure; and by 133 cntr/ha with the application of 80 metric tons/ha of manure, while that in the control area (non-fertilized) was 122 cntr/ha.

Of the active substances applied with equal amounts of manure and mineral fertilizers, organic fertilizers were most advantageous for the yield of tubers. The application of lime to hemp at a rate sufficient to raise the hydrolytic acidity of the soil by one unit had no effect on potato yield.

Backgrounds of varying fertility, created by the prolonged and systematic application of organic and mineral fertilizers, differed in their effect on the grain yield of spring wheat. It doubled where manure was applied for a long time to hemp at a rate of 40 metric tons/ha. A decrease in the amount of manure to 20 metric tons/ha reduced the wheat yield by 7%, while an increase of manure to 80 metric tons/ha, increased the wheat yield by 17%. In comparing the effect of organic and mineral fertilizers applied in equal amounts, one finds that the effect of manure is somewhat better. The application of lime to hemp against a background of longstanding use of manure and mineral fertilizers, as well as against a non-fertilized background had no positive effect on the yield of spring wheat.

The results of the experiment show that the yield of barley grain increased also when the amount of fertilizers was increased and with their increased time of application. Against a background of mineral fertilizers the highest yield (33.1 cntr/ha) was obtained with an optimum amount of $N_{120}P_{90}K_{90}$. The yield of barley against a background of 40 metric tons/ha of manure was 4.4 cntr/ha, or 15%, higher than after mineral fertilizers applied in an amount equal to 40 metric tons/ha of manure.

The residual effect of lime on non-fertilized soil and against a background of mineral fertilizers had a great effect on the increase in the yield of barley. The application of lime against a background of 40 metric tons/ha of manure had a negative effect. As far as the yield of oats is concerned, it was by 4.6 cntr/ha, or 17%, higher when NKP was applied in an amount equal to 40 metric tons/ha of manure than when 40 metric tons/ha of manure were used.

The highest yield of hay from clover was obtained when the repeated application of 20 metric tons/ha of manure amounted to 48.4 cntr/ha. The yield of clover decreased by 6.8 cntr/ha when the rate of manure application was increased from 20 to 80 metric tons/ha.

A study of the root system of clover showed that the amount of roots, as well as the amount and weight of nodules, decreased when the amount of fertilizers was increased and they were applied for a long time. In the non-fertilized plot, the weight of roots was 1.5-2 times higher than in the plot where 80 metric tons/ha of manure were used. The weight of a thousand nodules grown in the unfertilized plot was 0.183 g, 0.093 g against a background of 20 metric tons/ha of manure, and 0.032 g against a background of 80 metric tons/ha of manure.

The yield of hay from perennial legume-grass mixtures increased after 2 years as a result of the increase of the amount of manure. The increase in hay yield against the background of the prolonged use of manure was 34 cntr/ha, when 20 metric tons/ha of manure were applied, 54 cntr/ha with 40 metric tons/ha of manure, and 80 cntr/ha with 80 metric tons/ha of manure. The increase was slightly lower against the background of mineral fertilizers amounting to 13 cntr/ha with $N_{60}P_{45}K_{45}$, 33 cntr/ha with $N_{120}P_{90}K_{90}$, and 66 cntr/ha with $N_{200}P_{100}K_{240}$, while in the control plot with perennial grasses it was 55 cntr/ha.

When comparing the yield of hay from perennial grasses obtained from the application of 40 metric tons/ha of manure and from that of mineral fertilizers applied at an equivalent rate, one sees that its yield is higher under the prolonged application of mineral fertilizers. The increase in yield was 12 cntr/ha, or 22%, as a result of the better development of grasses. A single application of lime at the rate sufficient to raise the hydrolytic acidity of the soil by one unit had a positive effect on the yield of perennial grasses.

Conclusions

1. The prolonged and systematic application of manure, as well as the seeding of perennial legume-grass mixtures increase the humus content in the soil. The highest accumulation of humus occurs in the plowed layer, and in the lower layers of the soil under the prolonged application of high amounts of manure.

2. The amount of organic matter in manure which changed into humus varied from 14%-30%. The mineralization of organic substances added to the soil under hemp increased with increasing amounts of manure and reached a maximum (86%) with annual rates of manure of 80 metric tons/ha.

3. When manure and mineral fertilizers are applied together, the amount of humus in the soil does not decrease as compared to that when the same amount of manure is applied singly.

4. The simultaneous application of manure and lime promotes the accumulation of humus in the soil, while the application of lime against a background of mineral fertilizers intensifies the mineralization of organic matter.

5. When fertilizers are systematically applied to the soil, the content of mobile humus increases, whereby the amount of water-soluble humus in the soil to which mineral fertilizers are applied is higher than when manure is used.

6. Mineral fertilizers, applied in optimum amounts of $N_{120}P_{90}K_{90}$ (or equivalent to 40 metric tons/ha of manure) give higher yields of hemp and certain other agricultural crops in the first year than did the manure, but later their negative influence on the fertility of soil becomes felt, and the yield of hemp, potatoes, spring wheat, barley, and clover after manure exceeds that after mineral fertilizers.

7. Under the prolonged application of fertilizers, the stem length and yield of fiber, and the count and strength of long fiber are higher after manure than after mineral fertilizers, independent of the crop preceding hemp and the amount of fertilizer used.

Received March 28, 1960

BIBLIOGRAPHY

1. BEL'CHIKOVA, N. P. 1948. Change in the content and composition of organic matter in typical sierozem under the prolonged application of manure and mineral fertilizers. Pochvovedeniye, No. 1.
2. VAKSMAN, S. 1937. Humus. Sel'khozgiz.
3. VIL'YAMS, V. R. 1939. Soil science with the principles of agriculture. Sel'khozgiz.
4. GORODNIY, N. G. 1954. Change of the main properties of soil and the yield of hemp under the influence of fertilizers. Trudy Lub. instituta. No. 24, Ukrsel'khozizdat.
5. GUSEV, S. P. 1940. Decomposition of organic matter in soil. Pochvovedeniye, No. 5.
6. KOSTYCHEV, P. A. 1949. Formation of chernozem. Sel'khozgiz.
7. KONONOVA, M. M. 1951. Problems of soil humus and modern objectives of its study. Izd. Akad. Nauk SSSR.
8. PRYANISHNIKOV, D. N. 1940. Agricultural chemistry. Sel'khozgiz.
9. RUSSELL, E. W. 1955. Soil conditions and the growth of plants. Sel'khozgiz.
10. SOKOLOVSKIY, A. N. 1956. Agricultural soil science. Sel'khozgiz.
11. TYURIN, I. V. 1940. From the results of a study of the composition of humus in the soils of the USSR. Problemy sovremennogo pochvovedeniya. Collection No. 11. Moscow-Leningrad.
12. FRANTSENSON, V. A. 1939. Varieties of forest steppe and podzolic soils of various degrees of moisture. Pochvovedeniye, No. 7.
13. CHIZHEVSKIY, M. G. 1957. Development of theoretical bases for an agricultural system. Zemledeliye. No. 11.
14. SHKONDE, E. I. 1939. The role of fertilizers in the accumulation of soil humus. Udobreniye i urozhay. No. 1.
15. SALTER, R. M. and F. Y. GRENN. 1933. American Society of Agronomy. No. 25.

CHEMISTRY OF ORTSTEINS IN SOD-PODZOLIC SOILS

B. N. POL'SKIY, Sumy Pedagogical Institute

As we know, new formations in the form of ortsteins are found in bog, podzolic, and certain forest steppe soils. They are rounded, pellet-like formations ranging in diameter from a fraction of a millimeter to several millimeters. Their maximum accumulation in podzolic soils is found generally at the boundary of the podzolic A_2 horizon with the illuvial B horizon; in bog soils the depth of their accumulation varies greatly. The relative amounts of new formations of ortstein may be exceedingly great. Thus according to our investigations, the sandy peat-bog soils of the second floodplain terrace of the Oka River (Izhev rayon, Ryazan' Oblast') contained 30%-40% ortstein, and in certain cases more than 50% of the weight of the soil. There are known cases when new formations of the ortstein type in the form of ore-like deposits were mined industrially. In this respect it is interesting to study the chemical composition of ortsteins, which to this day has been insufficiently examined in the literature.

Until now it has been established that ortsteins are primarily iron concretions. Rode (2) pointed out that: "The accumulation of iron and humic substances is often accompanied by the formation of ortstein. Ortstein concretions are new formations which contain in addition to silica a large amount of sesquioxides, and in certain cases also humus." Approximately the same ortstein composition was found in his time by V. R. Vil'yams, who associated the formation of ortstein with the activity of anaerobic bacteria. He noted specifically that ortstein was very rich in phosphorous compounds. Vil'yams believed that the reason for this was biogenic accumulation in the soil resulting from the activity of various plant organisms.

However, the numerical material available in the literature which would substantiate the foregoing and similar assumptions is very scarce. A characterization of the chemical composition of ortstein in podzolic soils is really found only in the work of Gemmerling (1). In this work the author discusses the formation of the illuvial horizon and the accumulation in it of various compounds, and briefly examines the characteristics of the chemical composition of ortstein in podzolic soils. According to the data of Gemmerling, the total content of iron and certain other elements in the ortstein of podzolic soils is the following (Table 1).

As can be seen from Table 1, the ortstein is primarily rich in iron and also probably in aluminum. These data are not sufficient to substantiate the assumption of Vil'yams that ortstein concretions are very rich in phosphorous compounds. Ortstein is also fairly rich in manganese compounds. On the whole one may say that even though the analyses of Gemmerling do not give a sufficiently complete picture of the chemistry of ortstein, they speak of the presence in it of a considerable amount of iron.

We made several new determinations of the chemical composition of ortstein in sod-podzolic soils. The ortstein for analysis was taken from the moderately podzolic clay loam sod soil of the Tula forest reserve, the moderately podzolic, coarse clay loam sod soil of the Meshchera lowland (Spasskiy rayon, Ryazan' Oblast'), and the moderately podzolic clay loam sod soil of Moscow Oblast' (Kuntsev rayon). To obtain more comparable data, the ortstein was taken from soils of a similar texture and of the same degree of podzolization. The size of the ortsteins was approximately the same in all three cases and varied from 1-3 mm in diameter. At the same time they were taken from soils of various regions, which allowed us to determine certain features of their chemistry depending on the place of their formation.

The ortsteins taken for analysis differed greatly from each other morphologically. They were compact and almost black in the soils of the Tula reserve, while in the podzolic soil of the Meschchera lowland they were less compact, broke down under small pressures, and were of a light brownish cinnamon-brown color. The ortsteins of the soil in the Moscow Oblast' were similar in their compactness to those of the Tula reserve, but in contrast were of a cinnamon-brown color.

The results of summarized total chemical analyses are given in Table 2.

The ortsteins are not homogeneous in their chemical composition; they differ rather sharply from each other both in their Fe_2O_3 and MnO contents. The aluminum content varies less and always remains fairly high.

Table 1

Content, %	Sample No.					MnO, % (recalculated fr. Mn_3O_4)
	SiO_2	R_2O_3	Fe_2O_3	$Al_2O_3+P_2O_5$	Mn_3O_4	
15	67,02	15,99	5,26	10,73	—	—
17	72,83	20,60	9,88	10,72	2,27	2,11
18	65,23	21,14	11,13	10,01	5,13	4,77

Note: Comma represents decimal point.

Table 2

Total chemical composition of ortsteins in sod-podzolic soils

Area from which samples were taken	Content, %									
	Hygroscopic H_2O	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	MnO	SO_3
Tula reserves	2,51	58,65	21,21	5,06	15,17	0,41	1,02	1,14	15,47	0,51
Moscow Oblast'	3,02	73,01	18,65	8,04	10,09	0,52	0,94	1,02	5,75	0,43
Meshchera lowland	2,94	64,86	28,88	17,01	11,49	0,38	1,46	1,35	2,18	0,48

Note: Comma represents decimal point.

In this case we apparently have three definite types of ortstein: manganese, iron, and iron-manganese. It is interesting to note that as the chemical composition of ortsteins changes, their morphology changes accordingly. Thus, as the percentage of manganese increases they acquire a darker color and apparently become harder. True, the latter statement needs elaboration, since iron ortsteins, which have a more brown color than the manganese ortsteins, also in certain cases can be rather hard. As far as the content of other elements in them is concerned, we may note their definite richness in phosphorous compounds, as compared to the soils, which is in full agreement with the foregoing positions of V. R. Vil'yams.

The single determinations do not allow us to make any conclusions on the relative adaptation of the foregoing types of ortstein to definite areas, but we believe that these data allow the assumption to be made that the ortsteins of soils from various regions may have a certain specificity. The fact that the ortsteins analyzed were taken from similar soils allows us to assume that their specificity is determined not as much by the properties of the soil proper as by the landscape-related characteristics of its formation.

The determinations of the chemical composition of ortsteins taken from soils of various regions were recently supplemented by determinations of the chemical composition of ortsteins of various sizes taken from one and the same moderately podzolic gleyed sod soil of the Moscow Oblast' (Tables 3 and 4).

As we can see, the chemical composition of ortsteins from gleyed soil differs sharply from that of ortsteins from non-gleyed soils. In particular, they contain more iron and aluminum. As far as the changes in chemical composition are concerned, which are related to size, we

Table 3

Composition of ortsteins in moderately podzolic sod soil of different diameters

Diameter, mm	>3	2—3	1—2	0,5—1	0,25—0,5	<0,25
Content, %	17,32	28,55	36,87	13,11	4,15	Trace

Note: Comma represents decimal point.

Table 4

Total content of the major elements in ortsteins of various sizes

Diameter, mm	Content, %				
	SiO_2	R_2O_3	Fe_2O_3	$Al_2O_3+P_2O_5$	MnO
>3	45,01	48,11	27,20	20,91	3,29
2—3	44,98	42,16	26,06	22,10	3,32
1—2	48,24	44,87	25,03	19,84	3,10
0,5—1	53,87	39,76	23,64	16,12	2,97
0,25—0,5	58,08	35,81	21,09	14,72	2,99

Note: Comma represents decimal point.

can note a definite increase of silica and a relative decrease of sesquioxides and manganese compounds in small ortsteins. We believe that this indicates that particles of quartz, or other minerals, and rocks are contained in certain cases in the central part of the ortsteins on which compounds of iron, aluminum, and other elements are deposited in the same way as they are deposited on the faces of structural fragments in the B horizon of podzolic soils.

The foregoing leads to the conclusion that the chemical composition of ortsteins in sod-podzolic soils varies within rather wide limits and depends on a number of factors (regions of soil formation, size of the ortsteins, and soil moisture conditions). Ortstein concretions rich in iron and aluminum are found most frequently, but in certain cases (podzolic soils of the Tula reserves) the ortsteins are rather rich in manganese compounds. As the size of the ortsteins decreases, their iron and manganese content decreases.

Received February 22, 1960

BIBLIOGRAPHY

1. GEMMERLING, V. V. 1922. Certain data for the characterization of podzolic soils. Russkiy pochvoved. No. 4-5

2. RODE, A. A. 1955. Pochvovedeniye.

USE OF ANIONITES IN DETERMINING THE CONTENT OF AVAILABLE PHOSPHATES IN SOIL

L. V. SIDORINA, Scientific Institute of Fertilizers and Insecticides

The purpose of our work was to investigate the possibility of using anionites in the determination of available phosphates in the soil and also to establish the availability to plants of phosphate ions adsorbed by ionites in experiments with various soils.

In working out the problem of the method of determining available phosphates in the soil account was taken of the works of Tepe (13, 14), Bergmann (7, 8, 9), Boldin, Karpinskiy, Zamyatina (1), and others. When conducting experimental studies on plant nutrition, consideration was given to the investigations of Peterburgskiy, Arnon (5, 6), Nostitz (12), Converse (10), and others.

When working out the anionite method of determining available phosphates in the soil we used the EDE-10P anionite which belongs to the group of weakly basic anionites but posseses strongly basic properties because of the presence in it of quaternary ammonium groups. The exchange capacity of this anionite varies depending on the pH of the medium from 1.5 meq/g with a pH of 7 to 7.8 meq/g with a pH of 1 (2). In its ability to adsorb phosphorus from the soil the EDE-10P anionite is not inferior to the American strongly basic anionite Dowex, as Table 1 shows, which gives the results of an experiment on a 1-hour interaction between the anionites and the soil.

In our work we used the anionite in a carbonate form (treated with a 10% sodium carbonate solution and washed until the disappearance of an alkaline reaction in the wash water). In its interaction with the soil the carbonate anionite did not change the pH of the soil suspension. Chloride anionites should not be used in the method since they have an acid reaction.

The method of extracting the phosphate ion from the soil with anionites consisted in the following: an anionite sample with particles from 0.25-0.5 mm in diameter was added to 100 cm³ of distilled water and shaken with the soil. Before doing this the soil was ground and sieved through a sieve with 0.25 mm openings. After the anionite and the soil had interacted for 1 hour, the anionite was separated from the soil on a sieve with 0.25 mm openings by repeated washing. No phosphorus was found in the wash water. The phosphate anion was extracted from the air-dried anionite sample with 0.2 N HCl or a 10% solution of NaCl and the phosphorus in the filtrate was determined by the Denizhe method as modified by Schmuck and Kurilo.

To determine the influence of the time of interaction on the extraction of phosphorus from the soil (typical sierozem) with the anionite at varying ratios between the soil and the anionite, experiments were made in which the anionite was allowed to interact with the soil from 1 hour to 7 days. The results of these experiments are given in Table 2.

The time of interaction had a considerable effect on the separation of phosphorus from the soil when 10 g of soil were made to interact with 2 g of the anionite. With a 1:1 ratio between the soil and the anionite, exchange reactions proceeded rapidly. Since in the interaction between the soil and the anionite the exchange reaction takes place in both directions, it was interesting to study the course of the adsorption of phosphorus by the soil from the anionite. In order to do this, the anionite, saturated with phosphate ions, was treated with samples of various soils by shaking 10 g of soil with 2 g of the anionite in 100 ml of distilled water. The amount of phosphorus adsorbed by the soil from the anionite was determined from the difference between its amount in the anionite before and after its interaction with the soil. In spite of the weak adsorption of the phosphate ion from the anionite by the soil, exchange reactions still took place (Table 3).

The least amount of phosphorus adsorbed from the anionite by sod-podzolic soil is apparently attributable to the greater ability of the ion exchanger to sorb and hold phosphorus in an acid medium.

The exchange reactions during the interaction of the anionite containing phosphorus and the soil indicate that the ratio between the soil and the anionite plays an essential role in the extraction of phosphorus from the soil by anionite. The experiment made with typical sierozem confirmed the correctness of this assumption (Table 4). Even with a very wide ratio between the soil and the anionite, full extraction of the phosphorus from the soil was not achieved.

Table 1

Extraction of phosphorus from the soil (moderately podzolized, fine clay loam sod soil) with various anionites, mg P_2O_5/100 g of soil

Ratio between soil and anionite	Phosphorus extracted by the anionites	
	DOWEX	EDE-10P
1 : 0,5	12,5	15,2
1 : 1	15,6	21,5
1 : 2	22,0	31,0

Note: Comma represents decimal point.

Table 2

Influence of the time of interaction of the soil (10 g) with the anionite (2 g) on the phosphorus extraction

Duration of interaction	P_2O_5 mg/100 g of soil	Duration of interaction	P_2O_5 mg/100 g of soil
1 hour	3,8	7 days	5,7
1 day	4,2	10 minutes	7,5
2 days	4,9	30 "	7,5
3 "	4,9	24 hours	8,0
5 "	5,0	72 "	8,2

Note: Comma represents decimal point.

Table 3

Comparison of the magnitude of phosphate ion adsorption from the anionite containing phosphorus by various soils

Soil	P_2O_5 mg/100 of soil	In % of phosphorus in the anionite
Typical sierozem	260	19,4
Sod moderately podzolic, fine clay loam	140	10,0
Thick chernozem	240	17,9

Note: Comma represents decimal point.

The typical sierozem used in this experiment was characterized by a high content of available phosphates (22.9 mg of P_2O_5 soluble in 0.5 N CH_3COOH in 100 g of soil and 97.6 mg of P_2O_3 soluble in 0.5 N HCl by the F. V. Chirikov method in 100 g of soil).

In the experiments with sod-podzolic soil, taken from plots variously fertilized with phosphorus at the Dolgoprudnaya Agricultural chemistry Station, the amounts of available phosphorus also varied depending on the ratio between the soil and the anionite (Table 5). This relationship was very clear in the soil taken from plots which were better supplied with phosphorus. The results of the extraction of phosphorus from soil with the anionite were closest to those of an analysis of extracts by the Kirsanov method when the ratio between the soil and the anionite was 1:2.

The results of our experiments show that the anionite method deserves attention, but in order to obtain relative values, characterizing the content of available phosphorus in various soils, certain definite conditions of the extraction of phosphorus by anionites in relation to the pH of the soil, the ratio between soil and the anionite, the time of interaction, and the amount of phosphates in the soil, must be complied with during analysis. This will permit one to judge to what degree anionite methods extract exchangeable phosphates from the soil. We are continuing our investigations in this direction. The possibility of the uptake by plants of adsorbed ions from ion exchangers has been established in many experiments. However, not enough attention was paid to the degree of fixation of phosphate ions by ion exchangers in relation to the pH of the medium at which the saturation of the ionite with phosphate ions took place.

Our investigations called for the study of the

Table 4

Extraction of phosphorus by the anionite depending on the ratio between the soil and the anionite

Ratio of soil: anionite	P_2O_5/100 g of soil
1 : 1	8,0
1 : 5	19,0
1 : 7,5	27,0
1 : 10	36,0

Note: Comma represents decimal point.

Table 5

Comparative determinations of available phosphorus in a sod moderately podzolized clay loam (long-term experiment with mineral fertilizers applications) by various methods

Amount of P_2O_5 added during one crop rotation, kg/ha	P_2O_5 found, mg/100 g of soil				
	0.2 N HCl (according to Kirsanov)	0.5 N CH_3COOH (according to Chirikov)	According to the anionite method at soil: anionite ratios of		
			1 : 0,5	1 : 1	1 : 2
0	4,2	2,3	2,2	2,5	3,0
200	7,8	2,6	6,0	7,0	8,0
400	19,8	14,0	12,7	13,0	17,0
600	20,8	15,6	—	15,0	21,0

Note: Comma represents decimal point.

availability to plants of the phosphate ion in such an anionite in which the adsorbed phosphate ions are only in an exchangeable and not water-soluble form, and also for the study of the best conditions for the utilization of adsorbed phosphate ions in various soils.

To study these problems pot experiments were made with wheat on typical sierozem, thick chernozem, and sod moderately podzolic, fine clay loam. The experiments were made in glass pots 16 x 30 cm. Each pot was supplied by 0.5 g of K_2O and nitrogen. The amount of phosphorus was 0.25 g P_2O_5 per pot. The phosphorus was either in the form of monocalcium phosphate or in the form of adsorbed phosphorus with the EDE-10P anionite containing phosphorus.

Taking into account the differential availability of the adsorbed phosphate ion depending on the reaction of the medium at which the anionite was enriched with phosphorus, an anionite was used in the experiment which was treated with a solution of H_3PO_4 or K_2HPO_4. On treatment with a solution of phosphoric acid an anionite was obtained which contained 24% P_2O_5, whereby a large part of the phosphates slowly (in analytically measurable quantities) entered the water extract; however, when saturated with di-potassium phosphate, the anionite contained 7% P_2O_5 and that only in an exchangeable form.

The availability of the sorbed phosphate ion to plants was studied against a background poor and rich in anions which may contribute to the removal of the phosphate ions into the solution. Nitrogen was added against the background poor in anions in the form of urea in two stages (at the beginning of the experiment and as top dressing); potassium was added in an adsorbed form with the KU-2 cationite. Nitrogen was added against the background rich in anions in the form of calcium nitrate, while potassium was added in the form of potassium chloride; in addition, sodium chloride was added for the same purpose of creating a background rich in anions. The results of the experiment are given in Table 6.

There was no substantial difference in the development of plants and in yield in plots with water-soluble and adsorbed phosphorus on typical sierozem, thick chernozem, and sod moderately podzolic, fine clay loam.

The plants took up adsorbed phosphorus equally well against all backgrounds. The addition to the soil solution of anions in the form of soluble salts had no positive effect on the uptake of adsorbed phosphorus by plants.

Conclusions

Determinations of the content of available phosphates in the soil by means of EDE-10P anionites and the experimental study of the availability of variously adsorbed phosphate ions by plants showed that:

1. With a narrow ratio between the soil (typical sierozem) and the anionite (1:0.2) the time of interaction of the anionite with the soil has a substantial influence on the extraction of phosphorus from the soil.

Table 6

Effectiveness of anionites enriched in phosphorus by various methods (yield increments in grams and removal of phosphorus from fertilizers in mg P_2O_5 per pot)

Sources of phosphorus against a background of NK	$CO(NH_2)_2+K$ (cationite)		$Ca(NO_3)_2 \cdot 4H_2O+KCl$		$Ca(NO_3)_2 \cdot 4H_2O+$ $+KCl+NaCl$	
	Yield	Removal	Yield	Removal	Yield	Removal
Experiment with a typical sierozem						
$Ca(H_2PO_4)_2 \cdot 2H_2O$	13,6	39,4	10,6	29,6	16,6	48,4
Anionite treated with H_3PO_4	15,6	52,2	10,6	30,3	20,0	52,9
Anionite treated with K_2HPO_4	16,7	65,2	9,1	35,2	15,6	53,2
Background (NK)	23,2	92,6	29,2	107,5	18,2	68,5
Experiment with moderately podzolic, fine clay loam						
$Ca(H_2PO_4)_2 \cdot 2H_2O$	10,7	43,9	15,4	89,3	21,3	88,1
Anionite treated with H_3PO_4	10,4	50,7	16,5	84,9	18,0	84,8
Anionite treated with K_2HPO_4	9,1	54,4	16,5	79,2	15,0	74,7
Background (NK)	34,2	125,0	26,4	102,9	18,1	84,1
Experiment with thick chernozem						
$Ca(H_2PO_4)_2 \cdot 2H_2O$	1,9	35,1	12,8	69,9	17,4	66,5
Anionite treated with H_3PO_4	7,0	52,5	15,2	62,7	19,7	83,5
Anionite treated with K_2HPO_4	9,2	46,5	13,6	62,7	19,1	68,5
Background (NK)	28,6	99,8	24,0	96,6	11,2	55,9

Note: Comma represents decimal point.

With a 1:1 ratio, more than 90% of the phosphates extracted from the soil with the anionite, is adsorbed within 1 hour.

2. The adsorption by the soils (typical sierozem, thick chernozem, and sod moderately podzolic, fine clay loam) of phosphorus from an anionite rich in phosphate ions points to the presence of reversible exchange reactions between the soil and the anionite.

3. During the extraction of phosphorus by the anionite from the soil (typical sierozem and sod moderately podzolic, fine clay loam) a substantial role is played by the ratio between the soil and the anionite: the wider this ratio is the more phosphorus is extracted by the anionite. This relationship is most pronounced in soils with a high content of available phosphorus.

4. To obtain comparable values characterizing the content of exchangeable phosphorus in various soils, it is necessary to work out definite conditions for the extraction of phosphates with anionites depending on the pH of the soil, the ratio between the soil and the anionite, the time of interaction, and the amount of available phosphates in the soil.

5. In pot experiments with wheat on typical sierozem, thick chernozem, and sod moderately podzolic fine clay loam the adsorbed phosphate ion (weakly and strongly sorbed) is not inferior to the water-soluble phosphate ion in its effect on yield and the uptake of phosphorus.

6. The addition of anions of water-soluble salts to the soil had no positive effect on the availability of phosphorus adsorbed by the anionite to plants.

BIBLIOGRAPHY

1. KARPINSKIY, N. P. and V. B. ZAMYATINA. 1958. Phosphate level of the soil. Pochvovedeniye, No. 11.

2. PASHKOV, A. B. and V. S. TITOV. 1958. Major characteristics of certain Soviet ionites. Khimicheskaya promyshlennost'. No. 5.

3. PETERBURGSKIY, A. V. 1945. Uptake of

potassium and other ions from the sorbed state by plants. (Author's summary).

4. AMER, F., D.R. BOULDIN, C.A. BLACK, and F.R. DUKE. 1955. Characterization of soil phosphorus by anion exchange resin adsorption and P^{32} equilibration. Plant and Soil. 6(4).

5. ARNON, D.I. and K.A. GROSSENBACHER. 1947. Nutrient culture of crops with the use of synthetic ion exchange materials. Soil Science. Vol. 64.

6. ARNON, D.I., and W.R. MEACHER. 1947. Factors influencing availability of plant nutrients from synthetic ion exchange materials. Soil Science. Vol. 64.

7. BERGMANN, W. 1958. Die Bedeutung der modernen Ionenaustauscher auf agrikulturchemischem Gebiet. Die Deutsche Landwirtschaft. No. 4.

8. BERGMANN, W. 1958. Methoden zur Ermittlung der mineralischen Bedürfnisse der Pflanzen. Handbuch der Pflanzenphysiologie von Ruhland. Vol. 4. Heidelberg, Springer Verl.

9. BERGMANN, W. 1958. Ermittlung der Nährstoffbedürftigkeit des Bodens. Handbuch der Pflanzenphysiologie von Ruhland. Vol. 4. Heidelberg, Springer Verl.

10. CONVERSE, C.D., N. GAMMON, and I.D. SAYRE. 1943. Use of ion exchange materials in studies on maize nutrition. Plant physiology. Vol. 18.

11. KICK, H. 1956. Vegetationsversuche zur Verfügbarkeit der an Wofatite (synthetische Ionenaustauscherharze) gebunden Ammonium-Kalium-Phosphationen. Pflanzenernährung, Düngung und Bodenkunde. 72 (117):49-56.

12. NOSTITZ, A. 1925. Zur Bedeutung der basisch austauschbaren Bodenärhstoffe für die Pflanzen und über Einwirkung des Kalkes auf die absorbierenden Bodenkörper. Landwirtschaftliche Versuchsstation. 105, 159.

13. TEPE, W. 1956. Die Bestimmung der Bodenleistung mit Ionenaustauscher im Hinblick auf die Ernährung der Pflanze. Landwirtschaftliche Forschung. Vol. 7, Supplement.

14. TEPE, W. 1956. Einfluss der H + HCO_3 Verhältnisses und der Selektivität bei der Bestimmung der Bodenleistung mit Ionenaustauschern. Pflanzenernährung, Düngung und Bodenkunde. 75 (120):222-227.

DETERMINATION OF AMMONIUM IN THE SOIL BY THE ACID EXTRACT METHOD

N. M. MAYBORODA, Krasnoyarsk Agricultural Institute

Ammonium in the soil must be determined in order to characterize microbiological processes in the supply of available nitrogen to plants (1-11). There is little dissolved amonium. It is mainly adsorbed by colloids from which it is practically impossible to extract with water. Ammonium in the adsorbed state is easily extracted with a solution of potassium (2, 3, 4, 5, 7, 8), or sodium (1, 2) chloride. It can be detected in a salt extract by means of the Nessler reagent.

Our investigations revealed that it is impossible to determine the ammonium content in chestnut soils, solonetzic soils, chernozems (especially if they are calcareous) accurately by means of potassium or sodium chloride. The results obtained are usually too low. This is attributable to the fact that in the course of the analysis of soils having a pH of more than 7 in the salt extract, ammonium is lost from the soil.

1. Soil adsorption complex $NH_4 + K^+ =$ Soil adsorption complex $K + NH_4^+$

2. $NH_4^+ + OH^- \rightarrow NH_4OH \rightarrow NH_3 + H_2O$.

The present article gives experimental data on the foregoing problem and presents a suggestion on the use of the acid extract method for determining ammonium in soils.

Various methods were compared under conditions eliminating the loss of ammonium from the soil. To do this the samples were ground, sieved through a sieve with 1 mm openings, and placed in flat-bottomed flasks which were filled with KCl, NaCl, and HCl solutions to remove the amonium from the soil. The flasks were connected by stoppers and rubber tubes to flat-bottomed 100 ml receiving flasks which were previously filled with 20 ml of a 0.001-N H_2SO_4 solution. Then the flasks were shaken for 30 minutes. After shaking, the solution in the receiving flasks was titrated with 0.001 N NaOH with a Congo red or methyl orange indicator. Parallel to it ammonium in the sulfuric acid solution in the receiving flask was determined colorimetrically. To avoid errors from the effect of microorganisms, 1 ml of toluene was added to 20 g of soil.

The standard methods of determining ammonium in the soil were used as a control, including shaking the 20 g sample for 30 minutes with 100 ml of a 1 N solution of KCl (5), or with 600 ml of 0.05 N NaCl (1, 2) and then determining ammonium in the filtrate by means of the Nessler reagent. The analyses were repeated many times.

The acid method of determining ammonium in the soil is based on the fact that ammonium is displaced from the soil by the hydrogen ion and immediately becomes bound to the excess 0.05 N HCl, forming the non-volatile compound NH_4Cl. Then the NH_4 ions interact with the Nessler reagent $K_2(HgI_4)$ and produce mercuric ammonium of a yellow color:

$$NH_4Cl + 2K_2(HgI_4) + 4KOH = HgOHg\,(NH_2)I + 7KI + KCl + 3H_2O.$$

The color of the tested solution is compared in the colorimeter with the color of the prepared standard solution with a known ammonium ion concentration in a unit volume.

Analytical Procedure

Twenty grams of soil are placed in a 500 ml flask to which 1 ml of tuolene and 200 ml of 0.05 N HCl[1] are added, and the entire content is shaken for 30 minutes and filtered. The first portions of the filtrate are again placed on the filter. Twenty milliliters of the pure extract are poured into a 200 ml volumetric flask and brought to volume with distilled water. The flask is shaken to mix the solution. Then 20 ml of the diluted solution (or a different amount, depending on the ammonium content in the soil) in the 200 ml volumetric flask are transferred to a 100 ml volumetric flask. About 50 ml of distilled water and 4 ml of a 25% solution of Seignette's salt are added to the flask in order to prevent the solution from clouding as a result of the precipitation of calcium and magnesium salts. Four milliliters of the Nessler reagent are added and the solution is brought to volume. Various amounts (10, 20 ml, etc) of the sample solution of ammonium chloride are added to the other 100 ml volumetric flasks in order to compare the intensity of the color in each flask in the colorimeter.

---

[1] Several concentrations of HCl were tested in the experiment; the article gives the concentration which insures reliable results. If a sulfuric acid solution is used for this purpose, the filtrate is sometimes more cloudy because of the precipitation of gypsum.

The ammonium content in the soil is calculated according to the formula:

$$X = \frac{a \cdot b \cdot 1000 \cdot k}{n \cdot l}$$

in mg per 1 kg of moist soil, where X is the ammonium content in 1 kg of soil; a is the number of ml of the sample solution in the 100 ml volumetric flask; b is the titrate of the sample solution (0.005 mg NH_4 in 1 ml); k is the colorimeter reading for the sample solution; l is the colorimeter reading for the solution tested; n is the soil sample in grams, corresponding to the volume of the filtrate in the 100 ml volumetric flask; and 1000 is to reduce the results to 1 kg of soil.

Reagents

1. 0.05 N HCl.
2. Toluene.

Table 1

Ammonium content in soils in relation to the method of determination

Soil	Depth, cm	pH of salt extract	Methods of extracting NH_4^+ KCl	NaCl	HCl
			In mg/kg of soil		
Moderately thick, leached clay loam chernozem	0—20	6,7	14,6	15,1	15,0
Thick, slightly leached clay loam chernozem	20—25	6,8	21,6	21,0	21,0
Moderately thick, ordinary clay loam chernozem	0—20	7,0	24,8	26,0	25,3
Dark-gray, podzolized forest soil	0—20	6,5	16,7	16,2	16,6
Fine clay loam sod-podzolic soil	0—20	6,4	12,3	13,0	12,4
	20—25	6,2	10,6	11,2	10,3
Moderately thick, solonchakized chernozem-meadow soil	0—10	7,2	13,1	13,6	16,8
	14—24	7,3	14,0	13,6	17,0
Thin, gravelly, calcareous southern chernozem	0—20	7,4	12,6	12,3	15,4
Dark-chestnut soil	0—10	7,3	15,7	15,0	18,3
	15—20	7,5	11,0	11,3	13,6

Note: The soil samples were kindly given us by the soil scientists T. Taktayeva, V. Gorbachev, and A. Gorelova.

Note: Comma represents decimal point.

Table 2

Comparison of various methods of determining ammonium in alkaline soils which had received ammonium sulfate

Soil	pH of the salt extract	Should have	Found KCl	NaCl	HCl
		in mg NH_4 per 1 kg of soil			
Dark-chestnut	7,3	30,7	22,3	24,3	29,0
Moderately thick, cal. chern.-meadow soil	7,2	38,4	30,0	32,3	37,7
Calcareous southern chernozem	7,4	27,6	23,6	24,7	27,0
Moderately columnar solonetz	7,9	24,5	17,9	17,9	24,5

Note: The column "should have" summarizes soil ammonium as determined by the HCl method with 15 mg NH_4^+ applied in the form of an ammonium sulfate solution.

Note: Comma represents decimal point.

3. 25% solution of Seignette's salt (2, 5).

4. Nessler reagent (1, 2, 5).

5. Sample solution of NH_4Cl. Exactly 0.7405 g of chemically pure NH_4Cl are dissolved and brought to 1 liter with distilled water. Part of the solution is again diluted 50 times. The last sample solution contains 0.005 mg NH_4 in 1 ml.

Results of Investigations

The experiment showed that the acid extract method gives the same results as salt extracts when determining ammonium in neutral and acid soils (Table 1).

The largest amounts of ammonium were found by the acid method in soils having a pH of >7. The main reason for the differences is the loss of ammonium in alkaline soils during their treatment with potassium or sodium chloride solutions. This is the only way in which the presence of ammonium in the receivers connected to the flasks in which the soil was shaken with the salt solution, can be explained. Nitrogen losses can also occur when filtering soil and during other operations. When analyzing soils with a pH of >7, containing a large amount of ammonium nitrogen, the losses of ammonium when using salt extract methods may reach 10 mg/kg of soil.

It is important to note that when the acid method of determining ammonium was used the results varied only occasionally by ±0.3 mg/kg of soil, but they most often agreed. A good agreement between individual tests when using the salt extract methods for the analysis of ammonium was obtained for neutral and acid soils, while they differed considerably (up to 5-7 mg) for alkaline soils.

The advantages of the acid method of determining ammonium are especially clear when analyzing alkaline soils to which ammonium fertilizers were added (Table 2).

These and other data (10, 11) show that ammonium fertilizers and manure should be applied deeper in alkaline soils. When they are applied to a shallow depth ammonium can be lost from the soil. This fact was noted when liquid manure was applied to the surface of solonetzic soils of the "solontsy" sovkhoz and ammonium fertilizers, to the surface of calcareous soils of the "Minderlin" sovkhoz, Krasnoyarsk Territory.

Conclusions

A simple acid extract method of determining ammonium in soils of varying acidities, which does not require complicated equipment has been worked out. The method allows the determination of ammonium in neutral, acid, and alkaline soils.

Received March 18, 1960

BIBLIOGRAPHY

1. Agricultural chemical methods of soil investigation. 1954. Izd. Akad. Nauk SSSR.
2. BOYKO, V. F., and I. K. TSITOVICH. 1955. Agricultural chemical laboratory. Sovetskaya nauka.
3. GEDROYTS, K. K. 1955. Selected works. Vol. 2.
4. KONEV, D. A. 1929. Methods of determining ammonium in soils. Nauchno-agronomicheskiy zhurnal. No. 2.
5. PETERBURGSKIY, A. V. 1959. Exercise book on agronomical chemistry. Sel'khozgiz.
6. PRYANISHNIKOV, D. N. 1953. Selected works. Vol. 2.
7. ALLISON, T. E., J. H. DOETSCH, and E. U. ROLLEW. 1951. Ammonium fixation and availability in Harpster clay loam. Soil Science. 72(3).
8. BENGTSSON, N. 1924. The determination of ammonia in soil. Soil Science. 18(4).
9. HARPER, H. 1924. The determination of ammonia in soil. Soil Science. 18(4).
10. MARTIN, S. P. and H. D. CHAPMAN. 1951. Volatilization of ammonia from surface fertilized soils. Soil Science. 71(1).
11. SCHREUEN, D. A. 1955. Loss of nitrogen from ammonium-containing fertilizers applied to calcareous soils of the Zuiderzee polders. Abstract in Soils and Fertilizers. 28 (3):255.

SOIL INVESTIGATIONS IN NORTHERN ALASKA

I. S. MIKHAYLOV, Arctic and Antarctic Scientific-Research Institute

The soils of sub polar regions have been studied little until now. The only summarized work devoted to them (8) is obsolete to a large extent. Following it, descriptions of soils only in individual areas of the Arctic and sub-Arctic appeared in the literature (1-5). The major role in the investigation of these soils was played by Soviet scientists.

Lately the soil scientists of Boston University have been studying the soil of Northern Alaska in the Point Barrow area in great detail. Articles devoted to the results of these studies (7, 10, 11, 12) contain extensive factual material and interesting conclusions.

The soils studied most fully are designated by the Americans as "Arctic Brown" soils. These soils develop in well-drained areas with a thick active layer on various rocks under moss-shrub vegetation where Salix, Dryas, and Cassiope predominate; they have a well-aerated profile, are not gleyed, and occupy a small part of Alaska. Below we give the morphological description of these soils (7).[1]

A_0 0-2 cm. Dark-brown to black, peaty (found only along the cracks).

A_1 2-20 cm. Dark reddish-brown, gravelly-sandy clay loam: well-defined granular structure, roots are frequently encountered.

A_2 20-45 cm. Brown, gravelly sand; considerable changes in color associated with the nature of the soil-forming parent material.

A_3 45-68 cm. Brown, gravelly sand; stratifications of brown, gray, and yellow sand.

C 68 cm and deeper. Gray gravel with a small amount of sand.

The foregoing soils have a well-defined brown horizon in the upper part of the profile. Color does not change over various soil-forming parent materials. The peaty litter is found only at the edges of frost cracks. There are no signs of gleization in the soil profile.

Particle-size analyses (Table 1) and the morphological descriptions of Arctic Brown soils show that they develop on silty sandy loams and clay loams. The prevalence of silt is explained by the American authors by the fact that they are the most stable under arctic conditions.

The chemical analyses of Arctic Brown soils are not complete, but permit one to judge to a certain degree of the nature of soil formation (Tables 2 and 3). It must be noted that the content of organic material in the soil was calculated differently. Drew and Tedrow (7) took it as equal to C x 1.724, while in the article of Tedrow and Hill (10) it was taken as C x 2. Therefore, we calculated the humus content by one system only, C x 1.724.

The American investigators indicate that one of the most characteristic features of Arctic Brown soils is the considerable accumulation of organic matter in the upper soil horizons, where the humus content varies from 11%-16% (Table 4). The amount of organic material decreases in the lower horizons down to an average of 1%, while the illuvial horizon is undefined.

There is an undoubtful relation between the color of the soil and the organic matter. Thus Drew and Tedrow report that after treating the soil with hydrogen peroxide, the brown color disappears (7).

The reaction of the medium is associated with the properties of the organic matter (its quantity and quality). The reaction of the humus horizons is acid (pH 3.5-4.3); the parent material has a neutral or even alkaline reaction.

The adsorption capacity of these soils is 19-20 meq per 100 g of soil, and decreases with depth to 1.8 meq (at a depth of 68 cm). The adsorption complex in the humus horizon is saturated only to 11%; saturation increases in the lower horizons, reaching 93% at a depth of 20-45 cm. Adsorbed Na comprises a considerable amount (5%-10%) of total adsorbed bases. There is an accumulation of acid organogenic products in the upper horizons. Therefore, in

---

[1] The English measurements were converted into metric units. The designation of horizons is given according to the nomenclature of American investigators.

Table 1

Particle-size analysis of Arctic Brown soil, % (7, 10)

Horizon	Depth, cm	Particle diameter, mm							
		2,0—1,0	1,0—0,5	0,5—0,25	0,25—0,1	0,1—0,05	0,05—0,002		<0,002
							0,05—0,005	0,005—0,009	
A_1	0—20	10,0	10,9	16,8	21,4	10,6	15,5		14,8
A_2	20—45	13,2	15,6	32,5	26,5	1,3	3,2		7,7
A_3	45—68	23,3	21,1	28,0	19,0	0,8	2,8		5,0
C	68 and deeper	26,2	23,7	20,0	16,6	1,3	6,0		6,2
A_1	0—20	0,0	0,1	6,4	30,6	23,7	23,8	4,9	10,6
A_2	20—38	0,1	0,5	5,7	29,6	27,8	21,9	4,9	9,5
B	38—61	0,0	0,1	10,9	41,8	20,3	12,7	3,7	10,2
C	61 and deeper	0,1	1,3	25,5	40,9	13,2	10,6	3,6	5,3

Note: Comma represents decimal point.

Table 2

Chemical data for Arctic Brown soil (7)

Horizon	Depth, cm	pH	Adsorption capacity	Exchangeable cations, meq/100 g of soil				Saturation	Humus	N	C : N
				Ca^{++}	K^{+}	Na^{+}	Mg^{++}	In %			
A_1	0—20	4,3	19,2	1,05	0,20	0,26	0,70	11,09	11,48	0,38	18/1
A_2	20—45	6,1	3,36	1,88	0,18	0,15	0,92	93,15	0,68	0,03	16/1
A_3^a	45—68	7,2	1,82	a	0,16	0,15	a	a	0,37	0,01	16/1
C^a	68 and deeper	8,2	1,82	a	0,10	0,03	a	a	0,57	0,02	16/1

---

[a] Free carbonates are found in these horizons.

Note: Comma represents decimal point.

its chemical properties, reaction, and saturation with bases this horizon differs sharply from the lower horizons, where acid organic substances moving in insignificant amounts from above are compensated for by bases released during weathering. It must be noted that the upper horizon is somewhat poor in alkali earth cations; which is associated either with their migration along the profile, or with their "mineral" origin. The distribution of alkali cations indicates that they accumulate biologically and may be associated with the characteristics of the chemistry of the vegetation of the region described.

When studying the migration of substances in the soil profile, the American investigators limit themselves to the determination of silica and sesquioxides in the colloidal fraction of the soil in conjunction with X-ray and thermal analyses of this fraction.

The results of analyses of the colloidal fraction are not complete. It is not clear whether the silica content is given as a percentage of the total composition or of its ignited portion. The impoverishment of the upper horizons in silica may only be apparent if one considers the great losses on ignition (42.1%). We calculated the amount of silica with respect to ignited soil and found that it changes little along the soil profile. The upper, humus horizon is somewhat poor in sesquioxides, which may be closely associated not only with the removal of sesquioxides, but also with the biological accumulation of other elements, especially alkali and alkali-earth cations. The sesquioxide accumulation horizon, which is so typical for podzolic soils, is lacking. The ratio between silica and sesquioxides remains unchanged along the profile.

Thus there is basis to doubt the presence of the podzolic process in the foregoing soils. The sod process is clearly pronounced and leads to the accumulation of organic matter in the humus horizon. Because of the peculiarities of biochemical processes, acid highly dispersed compounds predominate in the organic matter of the soil, which probably are able to form compounds

Table 3

Mineralogical composition and the results of partial chemical analysis of the colloidal fraction (7)

Horizon	Depth, cm	X-ray analysis	Thermal analysis	Total SiO_2	Total Al_2O_3	$\frac{SiO_2}{Al_2O_3}$	Total Fe_2O_3	Ignition loss	After treatment (according to Jeffries) Fe_2O_3	After treatment (according to Jeffries) Al_2O_3
				In %			In %		In %	
A_1	0—20	Silicates, a small amt. of kaolinite, and traces of quartz	Illite-like clay minerals predominate. There is a small amount of kaolinite. The organic matter is stable	38,5	9,5	7,0	6,6	42,1	4,3	1,9
A_2	20—45	Same	Illite-like clay minerals predominate with a small amount of kaolinite	44,4	17,8	4,2	10,0	16,4	7,6	3,1
A_3	45—68	"	"	46,5	16,8	4,7	12,0	13,9	7,3	2,0
C	68	"	"	51,3	21,7	4,0	8,9	10,8	5,5	1,3

Note: Comma represents decimal point.

Table 4

Humus of Arctic Brown soils (10) on various soil-forming parent materials

Horizon	Soil-forming parent material: Sandstone elluvium	Loess-like clay loam	Gravelly clay loam
A	11,0	16,2	14,8
B	1,6	5,8	1,0
C	1,9	1,3	0,7

Note: Comma represents decimal point.

with sesquioxides and migrate down the soil profile. This assumption is substantiated by the results of analyses of the organic matter and the content of sesquioxides in the colloidal fraction. The analyses also show that organic matter accumulates at the permafrost boundary. But these processes are probably characteristic of only certain Arctic Brown soils which develop on coarse deposits.

Occasional cases of the podzolization of soils on coarse deposits may, of course, occur in the tundra, as was mentioned by Liverovskiy (5), and Gorodkov (1), but they are intrazonal formations.

The results of morphological descriptions and chemical analyses show that the American investigators, guided primarily by only one morphological index — color, have combined various soils (for instance, brown arctic acids, non-podzolized soils, podzolized soils, and calcareous soils) into one group under the name of Arctic Brown soil. Thus the classification Arctic Brown soils as referred to any soil group requires further careful study.

The second debatable conclusion made by the American investigators is their recognition of Arctic Brown soils as typical zonal soils of the tundra zone. They consider gleyey tundra soils, which are most widespread in this zone, as intrazonal hydromorphic soils — "the northern extension of gleyey-bog forest soils" (Fig. 1).

At the same time, the most typical, zonal soils of this region are those soils which develop in gently undulating areas without ground water supply in parent material of a medium texture. Under these conditions gleyey tundra soils form in the sub-arctic. Their gleization is not due to the proximity of ground water, but to the conditions of development of the seasonally thawed layer, underlain by permafrost. Excessive moisture is created by snow melting in spring, the thawing of ground ice, precipitation, and moisture condensation. The presence of a water barrier in the form of a permafrost prevents moisture migration beyond the limits of the soil profile. As a result, a stagnant water regime is established in gently undulating areas

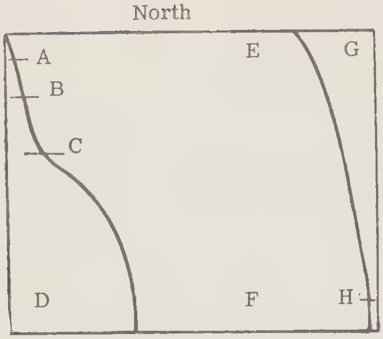

Fig. 1. - Relationship between the soils of dry and wet areas in the tundra and taiga zones.
A - arctic brown; B - sub-arctic brown; C - embryonic podzols; D - podzols; E - tundra soils; F - gleyey soils; G - bogs on permafrost; H - bogs.

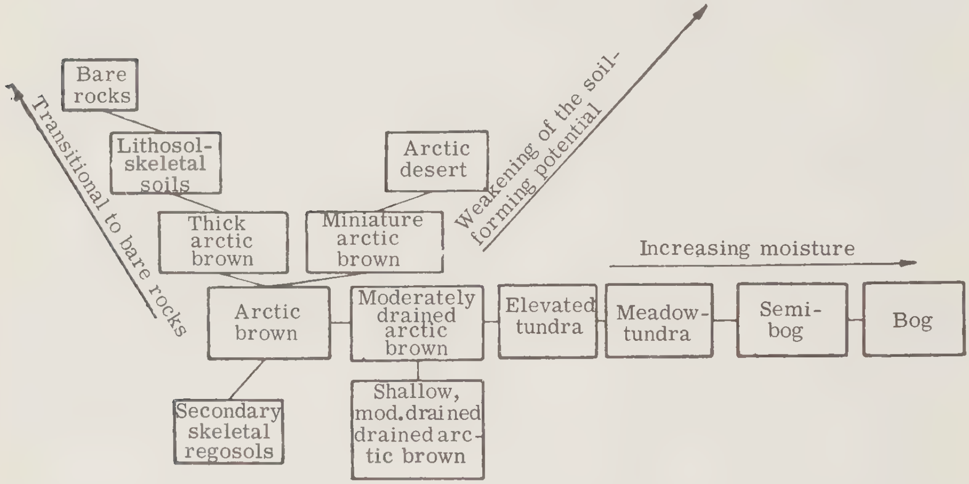
Bare rocks
Lithosol-skeletal soils
Thick arctic brown
Arctic desert
Miniature arctic brown
Transitional to bare rocks
Weakening of the soil-forming potential
Increasing moisture
Arctic brown
Moderately drained arctic brown
Elevated tundra
Meadow-tundra
Semi-bog
Bog
Secondary skeletal regosols
Shallow, mod.drained drained arctic brown

Fig. 2. - Distribution of soils in relation to soil-forming factors.

Steep slopes, bluffs, individual well-drained areas with coarse-textured material, where, because of lateral flow and deep thawing, the moisture migrates beyond the limits of the soil profile and well-aerated soils may develop, are the exception. Such areas, as stressed by the American investigators themselves, are very limited in the tundra. Therefore, it is illogical to consider something as typical which is not the rule, but the exception, as the Arctic Brown soils are in the tundra. It is most correct to retain the point of view of earlier investigators, such as K. D. Glinka, Yu. A. Liverovskiy, and Marbuta, who believed gleyey tundra soils to belong to the zonal group.

The American investigators classify the soils of Northern Alaska according to the nature of soil-forming factors and, primarily, according to the moisture content of the soil (Fig. 2). According to the moisture content, they distinguish between typical Arctic Brown soils, moderately drained Arctic Brown soils, elevated tundra soils, meadow-tundra soils, semi-bog soils, and bog soils.

We have already discussed the Arctic Brown soils earlier. The moderately drained varieties are transitional to tundra soils. Individual features of gleization are found in the soil profile, and the litter increases.

Tundra soils, as already mentioned, are the most widespread group. They are found on flat watersheds, on gentle slopes, and in river valleys. The upper horizons of these soils usually vary in color from yellowish to brown in elevated tundras to dark-gray in meadow tundras. Gley processes in them alternate with aerobic processes. Therefore there are usually many ochrish spots, tongues, and veins in their profile. The reaction of the soil is acid, even though as mentioned by the American investigators, there are calcareous soils among them. An interesting feature of these soils is the considerable amount of organic matter in the permafrost below the seasonally thawing layer. Such an accumulation of organic matter probably arose during the development of the soil, but the mechanics of its penetration into the permafrost is not clear yet.

The mixing of soil material under the influence of frost action is being denied by the American investigators on the basis of field experiments. Garnet grains placed in soil did not undergo any noticeable changes for 2 years. Only solifluction on slopes disturbs the soil profile.

The American scientists distinguish bog soils in most wet areas, which develop as the peat horizon develops. Semi-bog soils have a peat horizon 20-40 cm thick; that of bog soils averages 1.5 m, reaching up to 6 m in individual cases. These soils are characterized by peat accumulation and well-defined gleyey processes, and a shallow permafrost table.

In addition to distinguishing soil varieties according to the moisture conditions of the profile, the American investigators take the thickness of the soil as a criterion for another series. The following soils are distinguished in this series: shallow Arctic Brown soils, developing on fine earth materials underlain at a small depth by rocks. Therefore these soils are much less thick, have well-defined genetic horizons, and are graveily, as a rule. Together with the shallow Arctic soils of dry areas, there are moderately drained soil varieties which are close to tundra soils; they exhibit individual signs of gleization. At the same time there is a pronounced accumulation of organic matter in the lower part of the profile of these soil varieties.

A further decrease of the thickness of soil leads to the formation of gravelly, skeletal varieties, having a discontinuous brown horizon not more than 2-3 cm thick. These soils are included in the "lithosol" group. The extreme member of this series consist of bare rocky surfaces lacking fine earths.

The American scientists consider fragmentary, undeveloped soils of alluvial, eolian, and colluvial deposits, which are well drained and have a shallow active layer, as belonging to a separate group. This soil group is designated as "regosol" by the American scientists.

They also distinguish another branch of soil development, where the nature of soil formation varies because of the more severe climatic conditions. These soils include miniature Arctic Brown soils and arctic desert soils. Unfortunately there is no detailed description of such soils in the works of the American investigators, and there is no mention of their relation to other soils.

Figure 1 clearly shows the distribution of soils depending on soil-forming factors. The major disadvantage of the scheme is that it is static. The authors do not show in what direction the soils develop and how the soil groups change. The solution of these problems would help to understand the genesis of the soils and the nature of soil formation.

The American authors indicate that there is a close relation between vegetation and soil. They emphasize the correspondence between certain soil groups and definite vegetation groups. However, they make a reservation that this correspondence is less stable in moist areas. In addition it is disturbed by the rapid changes in surrounding conditions, since vegetation reacts more rapidly to changes in the external medium.

These authors show that vegetation groups usually correspond to several soil varieties, and, on the contrary, several vegetative groups may be found in a number of cases on similar soils (11). The most widespread meadow, tundra, and brush vegetation groups are found on similar soils with similar moisture conditions. Differences are caused by differential snow cover thickness, the nature of winter winds, and other factors.

The foregoing scheme of the correspondence between soils and vegetation is of great interest, but is far from being perfect. A further study of these relationships must lead to a deeper understanding of their nature, and the establishment of soil-vegetative complexes.

The American authors repeatedly point to the complexity of Arctic soils and the wide distribution of microrelief forms. But at the same time they devote very little attention to the problems of microrelief and its relation to soils, even though the interrelationship between soils and microrelief in the tundra zone is very important. The difficulty of mapping the mosaic of tundra soil is also mentioned. In their opinion these difficulties can be surmounted either by mapping the microrelief and adding it to the soil map, or by determining and mapping the soil complexes of the tundra. Unfortunately, not a single article by the American investigators is provided with soil maps, which would have helped to understand more deeply the geographical pattern of soil distribution and its genesis.

The soil scientists who study the American Arctic admit the priority of Russian scientists, the founders of soil science, such as V. V. Dokuchayev, I. M. Sibirtsev, and K. D. Glinka. One of the articles begins thus: "Eighty years ago, when Dokuchayev established five natural soil zones, the first step was taken toward the systematic study of soils as natural bodies." They also recognize that the Soviet investigators were the first to study Arctic and sub-Arctic soils. Special mention is made of the work of V. N. Gorodkov, whom the American authors call an "experienced arctic soil scientist."

Received March 3, 1960

BIBLIOGRAPHY

1. GORODKOV, B. N. 1939. Characteristics of soil in the Arctic. Uzvestiya gosudarstvennogo geograficheskogo obshchestva. 71(10).

2. GORODKOV, B. N. 1956. Vegetation and soils of Kotel'nyy Island. In the book: Vegetation of the Far North of the USSR and its reclamation. No. 2.

3. IVANOV, I. M. 1933. Soil formations in the icy zone. Trudy Arkticheskogo Instituta. Vol. 12.

4. LIVEROVSKIY, YU. A. 1934. Soils of the tundras of the Northern Territory. Trudy Polyarnoy Komissii. No. 19.

5. LIVEROVSKIY, YU. A. 1939. Soils of the northeastern European USSR. In the book: Soils of the USSR. Vol. 2.

6. DANSCRAU, P. 1954. Studies of Central Baffin vegetation. I. Bray Island, vegetation. No. 5-6.

7. DREW, I. V. and I. C. F. TEDROW. 1957. Pedology of an Arctic Brown profile near Point Barrow, Alaska. Soil Science Society of America, Proceedings. Vol. 21.

8. MEINARDUS, W. 1930. Boden der kalten Region. Handbuch der Bodenlehre. No. 3.

9. SMITH, I. 1956. Some moving soils in Spitsbergen. Journal of Soil Science. No. 1.

10. TEDROW, I. C. F. and D. E. HILL. 1955. Arctic Brown soils. Science. Vol. 80.

11. TEDROW, I. C. F. and I. E. CANTLON. 1958. Concept of soil formation and classification in Arctic regions. Arctic. 11(3).

12. TEDROW, I. C. F., I. V. DREW, D. E. HILL, and L. A. DOUGLAS. 1958. Major genetic soils of the Arctic Slope of Alaska. Journal of Soil Science. 9 (1).

REVIEWS

SOIL SOLUTIONS OF THE SOUTHERN PART OF THE FOREST ZONE AND THEIR ROLE IN CONTEMPORARY SOIL PROCESSES

I. N. SKRYNNIKOVA

The recently issued book of I. N. Skrynnikova represents an extensive experimental-theoretical study of the contemporary tendency of the soil process in the southern part of the forest zone of the Central Russian Plain (Moscow Oblast'). The work is based on the study of the seasonal dynamics of the composition of soil solutions squeezed out in a press. The subject and the conclusions of the author are so important that they should not be left without attention.

I. N. Skrynnikova notes great seasonal changes in the composition of soil solutions from the Moscow Oblast' and the influence of the nature of contemporary vegetation on it. The composition of the solutions forms in the A_0 and A_1 horizons. It changes greatly during vertical percolation in the following direction, according to the author: free organic acids and partially their salts are decomposed by microorganisms and also precipitate from the solutions in the A_1 horizon, as a result of which the total concentration of soil solutions in the A_2 and B horizons decreases sharply. The small amount of organic matter reaching these horizons with the solutions is present there in the form of ammonium and calcium salts. In interpreting the results obtained, the author pays special attention to the fact that the sod-podzolic soils of the Moscow Oblast' are not being wetted through in summer because of intense transpiration and evaporation. These soils are wetted through only in spring and autumn, which, in the author's opinion, is apparently insignificant. The regular wetting of these soils in summer to a depth of 10-12 cm is considered by the author as the cause of the maximum concentration of plant roots, humus, and microorganisms there.
The sharp drop in the concentration and seasonal changes of the composition of soil solutions in the A_2 and B horizons is considered by the author as an indication that the contemporary soil process is centered primarily in the A_0 and A_1 horizons and has almost no effect on the underlying A_2 and B horizons. Thus, in the author's opinion, the sod process of soil formation takes place over the almost inert "skeleton" of formerly strongly- and deeply-podzolized soils under the conditions of the Moscow Oblast' and is almost entirely confined within the limits of the A_0 and A_1 horizons (10-15 cm from the soil surface), where a continuous biological exchange of a definite supply of chemical elements, important for plant life, takes place.

In the author's opinion, the clay-forming and acid B horizon, characteristic of podzolic soils of the southern taiga, is isolated from the processes taking place in the A_0 and A_1 horizons, since the dynamics of the composition of soil solutions here is very weak. The author writes that "here slow, secular processes take place consisting primarily in the slow formation of clay in the soil (the decomposition in situ of large soil particles and the formation of clay). This process is accompanied by the hydrolysis of sesquioxides which become free and the acidification of the soil reaction. A great role in these processes, in particular in the acidification of the illuvial horizons of these soils, is played by the deep roots of broadleaf trees."

Finally the author concludes that "the podzol formation process under broadleaf forests, meadows, and fields in drained plains with clay loam mantle has ceased at the present time" and relates this evolutionary process to data on the history of landscape development during the post-glacial period and to the influence of the economic activity of man.

The novelty of the material collected by Skrynnikova and the great theoretical importance of her conclusions impels us to analyze and examine them thoroughly.

First of all let us analyze the problem of whether the method of studying the composition of soil solutions squeezed from a press is really the most effective in the study of the contemporary tendency of soil processes in the forest zone. Throughout the history of soil science, soil scientists used as a basis for relating soils to the podzolic group (in addition to their geographical location and their morphological structure) the results of analyses similar to those given by Skrynnikovà in the tables on the general characteristics of the soils studied by her (pp. 62-65). These soils have, in addition to features which may be interpreted as fossil, features which belong decidedly to contemporary soil formation, such as for instance an acid

---

[1] Collection "Contemporary soil processes in the forest zone." Akad. Nauk SSSR. 1959.

reaction, especially in the lower part of the profile, which is characteristic of sod-podzolic soils of the southern part of the forest zone. The study of soil solutions squeezed from them showed, however, that, judging by their pH the latter are slightly acid, sometimes neutral and even alkaline. But perhaps they are alkaline only in the Moscow Oblast', for which the conclusion was made that they lack contemporary podzolization? No, the soil solutions are also slightly alkaline at a somewhat greater depth (from 12, 20, 26 and 54 cm) in the soils of Karelia and the Lisin Forest Reservation, Leningrad Oblast', which were used for comparison.

The question naturally arises whether the soil solutions squeezed from a press characterize the true nature of the processes which take place in the foregoing soils. Actually one should not disregard the rather high and deeply reaching acidity of Moscow soils and judge of it only from the analysis of soil solutions no matter what their composition. It is clear that acidity cannot be "squeezed" into the solution, especially from the mineral horizons of podzolic soils. And this is perfectly clear since in podzolic soils not true but colloidally dissolved substances predominate. In addition, the acid elements in the mineral horizons are bound to a great extent to the solid phase of the soils. The work of Skrynnikova herself contains sufficient weighty facts which indicate that the solutions squeezed from podzolic soils do not characterize the composition of their liquid phase as a whole. Only part of the soil solution can be squeezed out under pressure, the other, and generally predominant part cannot be squeezed out. There are no reasons to think that both these parts, the one that can be squeezed out and the other that cannot, are identical in their composition.

The method of soil solutions can be very effective in the study of saline and other soils and be worth nothing in the study of podzolic soils. In the latter case the method of water extracts, in which we treat the soil with a considerable amount of water and from which we obtained a more accurate idea of the composition of the soil solution as a whole, even though it is diluted, may be preferable. The method of water extracts may be considered as being more rational also because under natural conditions the soil solutions modify, not on squeezing under pressure, but as a result of the free movement in the capillary soil system.

In relation to our critical approach to the method of soil solutions as applied to the study of processes in podzolic soils we would like to express our disagreement with the main conclusions drawn by Skrynnikova.

The author bases her conclusion about the absence of a contemporary podzolization process in the southern part of the forest zone primarily on the study of the concentration and composition of soil solutions at the transition from the A_0 and A_1 horizons to the A_2 and B horizons. However, the material in this section does not substantiate this conclusion, in our opinion. Let us try to substantiate this.

It cannot be expected that the concentration of the solution would not change within the profile of podzolic soils. The sources for the components of soil solutions are primarily the organogenic horizons — A_0 and A_1, and if they had no capacity whatsoever to retain these components, soil formation and the existence of plants would have been impossible. Every soil is a complicated system of filters of various types and not a completely open flowing channel.

A tremendous role in the formation of a soil profile with an eluvial regime is played by the chemical and physicochemical precipitation of substances from the solutions, whereby a differentiation of the acid-base properties between the precipitate and the filtrate occurs and the latter is removed from the horizon where precipitation occurs. The precipitate and the filtrate can be neutral only if they form as a result of the reaction between equivalent amounts of acids and bases of approximately the same strength. There is no doubt that soil formation in the southern part of the forest zone proceeds under conditions of the predominance of acids over bases. We believe that the sources of the acids are (integrally) organic C synthesized by the plants and atmospheric precipitation water, while those of bases are plant litter. Consequently, under these conditions the liquid phase of the solutions from which certain substances precipitate into the A_1 horizon, and which then penetrates into the underlying horizons, must be less concentrated than it is initially and more acid than the precipitated substances forming the A_1 horizon. These chemically natural and understandable phenomena explain best the cause and the mechanics of the formation of the A_2 horizon under the A_1 horizon in the profile of sod-podzolic soils.

Let us see how the data of Skrynnikova correspond to these assumptions. They serve as an excellent illustration of the fact that the A_1 horizon of sod-podzolic soils is the biochemical accumulator of bases and humic substances, since the solutions issuing from it are very poor in bases and organic matter. What is the importance of this to the underlying horizon, does it promote or inhibit its podzolization? We feel that it promotes podzolization, because the further the solution is from a state of saturation, the greater is its dissolving and migrational ability. But the lowering of the concentration of the solution alone is not enough to explain the possibility of contemporary podzolization, since this process is undoubtedly associated with the effect of specific humic acids on the mineral portion of the soil. Can we conclude from the data of Skrynnikova that the solutions issuing from the A_1 horizon are not only less concentrated than they were in the A_1 horizon, but are potentially more acid or unsaturated?

Unfortunately the method of soil solutions cannot give us absolutely accurate results to answer this question. It must be remembered that by squeezing soil solutions from the A_2 or B horizon we do not obtain the initial solution which flowed into these horizons from the overlying horizon, but a solution modified by its interaction with the given horizon and which is consequently less acid than it was initially. In addition, as we already mentioned, only part (generally the lesser) of the

Table 1

Content of organic matter in soil solutions (ml/liter) and acidity (meq H per 100 g of organic matter)

Soil in a spruce forest (1947-1948)

Horizon	June		August		September		October		April		May		June		July		August	
	Organ. matter	H	Organ. matter	H	Organ. matter	H	Organ. matter	H	Organ. matter	H	Organ. matter	H	Organ. matter	H	Organ. matter	H	Organ matter	H
A_0	560	152	2720	122	4308	63	5027	158	2190	110	6315	57	4353	90	11100	202	5853	390
A_1	90	700	356	455	372	100	212	255	254	283	211	220	235	634	753	206	460	268
A_2	20	1050	213	141	267	8	126	182	108	315	43	350	108	740	598	156	191	538
B	25	840	—	—	38	80	--	—	53	453	28	—	24	2300	58	1070	—	—

Soil in an oak forest (1947-1948)

Horizon	June		July		September		October		April		May		June		July		July		August		September	
	Orgn. matter		Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H	Orgn. matter	H
A_0	3797	123	—	—	—	—	8533	185	—	—	—	—	--	—	—	—	—	—	—	—	3173	452
A_1	148	115	289	267	341	100	214	70	284	4	140	107	160	81	323	173	188	277	508	100	764	7
A_1A_2	125	360	94	255	146	158	101	30	273	0	88	68	132	197	350	109	95	758	296	122	157	230
A_2	186	97	101	550	133	45	—	—	75	40	42	190	90	290	148	217	67	612	108	380	124	208
B	—	--	150	—	25	320	—	—	135	—	11	—	11	---	—	—	162	162	—	—	—	—

soil solution is squeezed out, which cannot characterize the soil solution as a whole. But even with all these shortcomings of the method of soil solutions, one may conclude on the basis of Skrynnikova's data that generally the non-saturation of the organic matter in soil solutions with bases increases at the exit from the A_1 horizon. Corresponding calculations were made by us on the basis of observations for the more typical Podushkino area. Table 1 gives the content of organic matter in solutions and acidity from organic acids (total titratable acid minus the acid from CO_2, expressed in meq H per dissolved organic matter). As can be seen from the data in the table, the non-saturation of the organic matter in the soil solutions is generally insignificant (considering that its full saturation capacity at pH of 7-8 is equal to about 500-600 meq) and generally increases in the A_2 and B horizons.

Thus, the conclusion of the author that the small amount of organic matter which reaches, with the solutions, the A_2 and B horizons of soils in the Moscow Oblast' is represented almost exclusively by ammonium and calcium salts, cannot be considered as correct, since it possesses a considerable, and sometimes even high, titratable acid. But the most important thing is that the conclusion is wrong because the organic matter in soil solutions from the A_2 and B horizons constitutes an insignificant portion of its total content in these horizons; penetrating into these horizons in the form of solutions, it becomes firmly bound to the mineral portion of the soils. Let us give you the following example. A tremendous amount of leached organic matter (up to 20%-30% of soil weight) sometimes accumulates in the humus-illuvial horizons of sandy podzols, which is precipitated with the hydrates of sesquioxides. However, the solubility of this organic matter in water is insignificant and we would make a big mistake if we would conclude on this basis that no solutions of organic matter penetrate into this horizon. This example shows that the methods of soil solutions or water extracts can give a very distorted idea of processes in podzolic soils when they are used with sufficient discrimination.

Let us examine another important problem. We cannot agree with the statement that the absence of regular leaching through the sod-podzolic soils in the Moscow Oblast' in summer excludes the possibility of the development of contemporary podzol-forming processes here. For the latter to take place it is sufficient that the soil be leached through every spring and autumn. In relation to this we cannot agree with the opinion of Skrynnikova that the depth of regular summer wetting of soils in the Moscow Oblast' to 10-12 cm is the cause of the formation of their accumulative layer ($A_0 + B$) at the same depth. Chernozems are wetted in summer even to a more shallow depth, but this does not interfere with the development of their humus horizon to a depth of one meter or more as a result of the utilization by plant roots of the moisture contents created in the deep horizons in autumn, winter, and spring. Skrynnikova writes herself that the biological productivity of broadleaf forests of the southern part of the forest zone is not inferior to that of meadow-mixed grass steppes. Then what should interfere with the formation of a thick humus horizon, such as in chernozem, in the soils of the Moscow region?

We are deeply convinced that the small thickness of the A_1 horizon in the sod-podzolic soils of the Moscow Oblast' is caused by their heavy and deep leaching during the spring and autumn, more accurately, by the complex of bioclimatic and biochemical causes, or even more precisely, by the fact that soil formation proceeds here not in the direction of a purely sod process (if such is possible at all) but is of the sod-podzolic type, and not by the lack of deep leaching in summer. This is evidenced first of all by the sharp and not gradual decrease in humus with depth; this is a typical feature of podzolic soils which is not encountered in other soil groups and is self-explanatory. It shows that during soil formation the humic substances sharply differentiate into two parts: a part which precipitates in the A_1 horizon (solid phase) and a non-precipitating part (liquid phase). The thickness of the A_1 horizon indicates here that the products of humus formation are capable precisely to this degree of precipitating with the available amount of bases and under the given climatic conditions. The excess of non-precipitating and more highly dispersed organic matter separates rapidly and not gradually from the precipitate in the form of a solution, i. e., from the A_1 horizon, and, filtering downward, forms the other necessary horizons of podzolic soils — the A_2 and B horizons, the origin of which is genetically related to precisely that discontinuous form of the A_1 horizon which occurs in podzolic soils.

The conclusion on the present-day cessation of the podzol-forming process in the southern part of the forest zone is debatable for other reasons also. It is in contradiction with the fact that the plowed soils of the Moscow and neighboring Oblasts' are acid and do not become neutral with time, and, consequently, require liming. And since liming must be repeated periodically it means that the acidity of the Moscow soils is not a relic, but is determined by the contemporary direction of the soil process.

The next problem is also very important. One cannot agree with the author that clay formation and acidification of the B horizon, characteristic of the sod-podzolic soils of the southern part of the forest zone, are completely isolated from the influence of products penetrating from the upper part of the soil profile, and that the agents of these processes are local agents, such as the root system of plants, microorganisms (?), and carbon dioxide. The explanation of these phenomena by the influence of the "root factor" does not sound very convincing. Moreover, the author does not present any data, even visual, on the content and volumetric distribution of plant roots in the B horizon. It is difficult to visualize how the pronounced, continuous, monolithic, and not local clay formation in the B horizon of sod-podzolic soils could take place under the influence of the generally scattered and almost non-branching plant roots. Even if we disregard the fact that the continuous clay-forming soil horizons are usually least inhabited by roots, the hypothesis of the "root factor" meets another objection of a general nature: the "root factor" is too universal to be related to the origin of horizons inherent to only certain soil groups.

The method of soil solutions should not be overestimated during the study of contemporary processes in podzolic soils. This is being done on the grounds that supposedly only this method allows analysis of natural soil solutions, while all methods using chemical reagents change the nature of soil compounds. As we tried to show, solutions squeezed from a press also cannot be considered as natural for podzolic soils. Far from all which is capable of moving in the natural profile of podzolic soils is squeezed into the solution. Without "vivisection," i. e., the deep penetration with various chemical and physicochemical methods into the body of the soil, one cannot disclose the actual processes taking place in it. The study of soil solutions is one of the possible methods, whereby it may be, literally, the most superficial of them (when speaking of podzolic soils), i. e., leaving out of the field of vision of the investigator the main products, properties, and processes which characterize these soils.

We do not extend our critical approach to the method of soil solutions to all soils and would like to say in conclusion that no method can be evaluated without the material obtained from its use. In this sense the work of Skrynnikova is very valuable against the general background of investigations devoted to the study of podzolic soils.

V. V. Ponomareva

CHRONICLE

SOIL SCIENCE AND GEOGRAPHY

K. P. GORSHENIN, Agricultural Institute, Omsk

Soil science is one of the youngest of the natural sciences in the field of agriculture. During the 80 years of its existence, soil science has developed greatly. The founder of soil science, V. V. Dokuchayev, aimed at utilizing its achievements in agriculture to the fullest.

Since the soil is a spatial formation and our science was initiated in the field, it is only natural that during soil studies in the field, geographical methods of designating soils were used along with other methods. However, in post-Dokuchayev times geography took the lead in soil science instead of being auxiliary. The soils were studied primarily as natural formations and the main task led to the determination of the geographical patterns of soil distribution. The views on soils expressed by our great soil scientist of that time, K. D. Glinka, belong to this period. In the introduction to his textbook on soil science (1915) he wrote: "To us soil is only a product of nature, a definite part of the core of the Earth... and we can study it as such, without bothering about the problem of how this product is related to man and his economic activity." It is not necessary to show how radically this view differs from the views of Dokuchayev on the tasks of the science. To be just, however, it must be noted that during Soviet times Glinka changed his mind on the tasks of soil science considerably.

The period of the domination of the geographical tendency in soil science is sometimes called the period of depression in our science. We do not think that this is entirely true. During this period material was collected which was necessary for the development of its general principles. But it is also true that if simultaneously with soil-geographical investigations, investigations had been conducted with the view of solving practical agricultural problems, based on the knowledge of soil, soil science would have made great achievements today.

The October Revolution and the reorganization of agriculture (its socialization) posed new problems to all agricultural sciences, including soil science. The soil scientists' were required to work out methods of studying soils as the major factor of agricultural production.

It is understandable that the development of the principal positions of Dokuchayev under the socialist regime required time and was accompanied by certain difficulties. There was a certain competition between two tendencies in the methods of soil study, the geographical trend, which considered the soil as a natural phenomenon, and the agronomical trend, which considered the soil as the principal means of production. A great role was played by Academician V. R. Vil'yams in reorganizing soil science for agronomical purposes.

It would seem that one could speak now of this controversy as something of the past. However, this is not true. From time to time certain voices are raised which again try to turn our science from the right path toward geographical sciences. Thus, for instance, Ryabchikov (2) tries to include soil science among geographical sciences and attempts to prove that its rightful place is among these sciences.

This is what A. M. Ryabchikov writes in his article: "The history of one of the most synthetic geographical specialties — soil science, which after the August 1948 session of the Academy of Agricultural Sciences was transferred to the biological faculty, is peculiar. However, the special position of soil departments at biological — soil faculties, and their separation from geographical faculties has a negative effect on the education of soil scientists, since they do not acquire enough knowledge of physiographic principles, of mapping methods, and of the geography of agriculture... We firmly believe that, as for soil science, so for geography, and for practical purposes, it would be better to train soil scientists at geographical faculties."

With these words the author clearly shows how far he is from understanding of the main tasks of soil science! In his opinion soil is not the major factor in agricultural production, but only a natural phenomenon. And the task of the science is not the solution of practical agricultural problems, but the cognition of physiographical principles. The author is right when he speaks of the necessity of a physiographical training of soil scientists. But this does not mean that the geographical method of soil investigation is the principal method. Soil-geographical investigations must be aimed primarily at determining the geographical patterns of soil distribution, as the main means of agricultural production. The lack of understanding of precisely this aspect of soil-geographical investigations is one of the reasons for such soil classifications, which, with the right introduction to them, actually show the soil only as a geographical phenomenon and are thus worth little to the science. In this respect a more correct (even though not quite correct) idea on the relation between soil science and the geographical sciences is set forth in the articles of Saushkin (3), who writes: "... when studying soils a distinction should be made between geographical soil science and general soil science."

To understand correctly and study soils as the major factor of production, it is not sufficient to be a geographer. It is necessary that the soil scientist understand the agronomical nature of soils. And precisely this, and no other understanding of soils, is the fundamental nature of soil science. It is understandable that such requirements cannot be set to a geographer, since he does not have the necessary biological and agronomical training. And without this there can be no full-fledged soil scientist.

It would be very unfortunate for soil science, if it would be incorporated into geographical sciences. And this, of course, cannot be. The principal means of agricultural production — soil, cannot be separated from the cycle of agricultural sciences. The fact that I found it necessary to write this note has nothing to do with the fear that soil science would be included in the cycle of geographical sciences. The reason for my note is a different one. The matter is that an article, similar to that of Ryabchikov, could confuse the young people, especially university students, who could easily accept purely geographical methods of soil study, the more so because the study of soils, as an element of the geographical landscape only, is much easier and simpler than the cognition of soils from the point of view of the solution of agricultural problems. After graduating from a university and starting production work, such young soil scientists would find themselves in a very difficult position.

All that was said previously does not mean that soil science should not be included among the disciplines of geographical faculties. It is indisputably necessary, since the soil is a component of that medium in which the biological and industrial activity of man takes place. But it is also indisputable that soil scientists should be trained at the biological and not at the geographical faculty. No matter how well trained is a geographer, he could never properly solve the problems of the utilization of soils in agriculture. The matter is that soil should be represented on a map not only in general, but the map must also be of an agronomical nature, which is not in the power of a geographer not having an agronomical background. As far as the geographical training of soil scientists is concerned, geography is sufficiently represented at biological faculties. And if one should wish for something in the training of soil scientists at universities, it is the strengthening of the agronomical foundation required by a soil scientist to solve problems of the proper utilization of soils, rather than the geographical one. Unfortunately, because of the present poor agronomical training of soil scientists at universities, the young soil scientists are often lost when they face agricultural and not geographical problems in the study of soil. This fact was mentioned in particular by local soil scientists at a seminar conducted by the soil scientists of the RSFSR at All-Union Institute of Fertilizers and Agricultural Soil Science this April.

In relation to this we would like to suggest to A. M. Ryabchikov that he read the article of I. S. Shchukin (4), which is included in this issue, in order to understand correctly the tasks of the science of soil. Shchukin writes: "When the time comes to decide about the place of any given scientific discipline in the scientific system, the most correct way of objectively solving the problem, in our opinion, is the following: first of all the given science must be correctly and exhaustively defined at the contemporary level of its development, the purpose of its study must be indicated, the aspects from which this science can be viewed must be described, and the necessary methodological procedures must be established."

The points of view from which soils must be studied are perfectly clear. They were already determined by Marx and Lenin, who considered the soil as the main means of agricultural production. These points of view, and no other, must serve as the basis for the study of soils, using various methods for this purpose. And there are many such methods. It would enter nobody's mind to include soil science in the cycle of physical or chemical sciences, only because both these sciences are widely used in the study of soils. There are even fewer reasons to include soil science in the cycle of geographical sciences only because geographical methods are used in the study of soils. Soil, which has a spatial distribution, is related to other geographical conditions. But if only this is used to include soil science in the geographical cycle, then it should also include all which is related to geographical conditions, including agronomy and animal husbandry. It is doubtful that the geographers would agree with such a wide understanding of the tasks of geography, even though agriculture as a whole is related to geography in the same manner. Soil science includes a section on the geography of soils, but this is not only the entire science, but not even its main part, since as agricultural geography, this is not the principal nature of agricultural sciences.

Received May 18, 1960

BIBLIOGRAPHY

1. GLINKA, K. D. 1915. Soil science.
2. RYABCHIKOV, A. M. 1960. Trends in the development of geography in universities. Vestnik Moskovskogo Universiteta, seriya V, Geografiya, No. 1.
3. SAUSHKIN, YU. G. 1959. Izvestiya Moskovskogo Gosudarstvennogo Universita. Biologiya, pochvovedeniye, geologiya, geografiya, No. 4.
4. SHCHUKIN, I. S. 1960. The place of geomorphology in the system of natural

sciences and its interrelationship with complex physiography. Vestnik Moskovskogo Universiteta, seriya V, Geografiya. No. 1.

From the Editors

At the request of Academician I. P. Gerasimov we include the following corrections to his article (written together with O. A. Chichagova) "Two soil profiles in the fields of the Rothamsted Experiment Station," published in "Pochvovedeniye," No. 3, 1960.

Owing to the oversight of the author a typographical error was made in Table 7 on page 85; the value numbers of two neighboring columns for the depth of 90-100 cm, giving the quantity of particles, 1-0.25 and from 0.25 to 0.05 mm in diameter, were transposed.

Printed			Should read		
90-100	22.08	2.28	90-100 cm	2.28	22.08

In his letter Academician I. P. Gerasimov notes that the foregoing values are mentioned in the note by A. A. Rode "How analytical data should not be used during the study of the genesis of soils" ("Pochvovedeniye," No. 11, 1960) as proof of the heterogeneity of the parent material of one of the Rothamsted soils described.

ABRAM FEDOROVICH IOFFE

Abram Fedorovich Ioffe died suddenly on October 14, 1960, a few days before his eightieth birthday. He was one of the outstanding Soviet physicists and the irreplaceable director of the unique in the World Agricultural Physics Institute of the All-Russian Lenin Agricultural Academy; an active member of the Academy of Sciences of the USSR; an honorary academician of the All-Union Academy of Agricultural Sciences; and a popular, scholarly communist.

Our country and science lost in him an outstanding scientist, who enriched physics with works of great importance, an initiator and proponent of the introduction of the most modern achievements of theoretical physics into agronomy and agricultural production, who trained a large corps of agricultural physicists.

An independent Agricultural Physics Institute was created in 1932 at the All-Russian Lenin Agricultural Academy at the suggestion of A. F. Ioffe, who directed it to his last day.

During the last 28 years, the new science of agricultural physics developed and strengthened in the Soviet Union under the constant and active leadership of A. F. Ioffe. It is being introduced more and more into practice and helps use the large agricultural reserves in production. The Agricultural Physics Institute is now a large scientific-research institution, equipped with the most modern instruments and laboratory equipment, located in a beautiful building, constructed especially for it, which contains greenhouses, an area with warmed soil, and a powerful gamma-installation for the irradiation of various items.

The persistence of A. F. Ioffe in introducing the most modern achievements of physics into the study of various aspects and processes of agricultural production resulted in that at the present time soil physics has developed at the Agricultural Physics Institute; ionized radiation and tagged atoms are used extensively; the photophysiology of plants is being developed; semi-conductors and polymers are widely used, agricultural machinery is being constructed and the processes of agricultural production are being automated. Many achievements of the Institute are widely used in agricultural production.

Under the leadership of A. F. Ioffe, studies have been initiated at the Agricultural Physics Institute on the mechanics of the effect of ionizing radiation on plants, which creates tremendous possibilities for radioselection.

Much strength was spent by Abram Fedorovich to prove the advantage and effectiveness of the use of certain types of films in vegetable growing. But now there is no doubt any more on their value, and cadres of vegetable growers who use protective films are increasing.

The major work, "Principles of Agricultural Physics" (1959), was published under the editorship of A. F. Ioffe.

The contribution of A. F. Ioffe to Soviet agronomical physics is tremendous, in the full sense of the word, and his services in this field will serve our country and our people.

Agricultural Physics Institute, Academy of
Agricultural Sciences, and Editorial
Office of "Pochvovedeniye"

BIBLIOGRAPHY

FACTORS OF SOIL FORMATION, GENESIS, GEOGRAPHY AND THE CARTOGRAPHY OF SOILS

1. Agricultural climatic handbook. 1960. Kiev, Gossel'izdat USSR (Upr. gidrometeosluzhby, Kiev, gidrometeorol. observatoriya): Trans-Carpathian Oblast'. 120 pp. with illustr. and maps. Bibliog. 35 refs. Chernovitsky Oblast'. 75 pp. with maps. Bibliog. 28 refs.

2. Agricultural climatic handbook for the West Kazakhstan Oblast'. 1960. Responsible editor, R. D. Kudrin. Alma-Ata, Kazgosizdat. 144 pp. with maps.

3. Agricultural climatic handbook for the Novgorod Oblast'. 1960. Leningrad, Gidrometeoizdat. 152 pp. with 2 maps sheets. Bibliog. pp. 141-142.

4. Agricultural climatic handbook for the Orlov Oblast'. 1960. Leningrad, Gidrometeoizdat. 92 pp. with maps.

5. Agricultural climatic handbook for the North Ossetian ASSR. 1960. Leningrad, Gidrometeoizdat. 120 pp. with maps.

6. Agricultural climatic handbook for the Checheno-Ingush ASSR. 1960. Groznyy, Checheno-Ingush. kn. izd. 128 pp. with graphs and maps. (Sev.-Kavkaz. upr. Gidrometeosluzhby). Bibliog. 30 refs.

7. ALEYNIKOV, A. A. 1960. Main problems in the study of Quarternary (antropogenic) deposits in the Northwestern USSR. Leningrad, Izd. Leningr. un-ta. 66 pp. with maps. Bibliog. pp. 60-65.

8. AMANBEKOV, KH. T. 1960. Characterization of soils and certain meliorative features of the Saran' city area and the area of the village of Shakhan, Karaganda Oblast'. Tr. In-ta pochvovedeniya Akad. Nauk KazSSR. Vol. 2: 92-126. Bibliog. 10 refs.

9. ARMAND, A. D. 1960. Relief development in the Khibiny mountains and the Khibiny plant (Kola peninsula). Author's summary of his dissertation for a candidate's degree in geographical sciences. (In-ta geogr. Akad. Nauk SSSR). Moscow. 18 pp.

10. VAYTEKUNAS, I. I. 1960. Soils of the lower reaches of the Neman River and their agricultural value. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Litov. s.-kh. akad.). Kaunas. 34 pp.

11. VAS'KOVSKIY, A. P. 1960. Geographical characteristics of soils in the forest region of the far northeastern USSR. Krayeved. zap. (Obl. krayeved. muzey. Magadan). No. 3:72-108. Bibliog. pp. 106-108.

12. VOLKOV, A. I. 1960. Soils of the eastern part of the old alluvial Dzhana-Dark'ya valley. Tr. In-ta pochvovedeniya Akad. Nauk KazSSR. Vol. 2:154-179, with maps. Bibliog. pp. 178-179.

13. VOLOBUYEV, V. R. 1960. Soil zones of Eurasia. Izv. Akad. Nauk SSSR. Ser. biol. No. 4:542-549. Bibliog. pp. 548-549.

14. VOLOBUYEV, V. R. 1960. Ecological-genetic analysis of the soil of the Azerbaydzhan SSR. Izv. Akad. Nauk AzSSR. Ser. biol. i med. nauk. No. 3:3-16, with maps.

15. VORONOVA, YE. P. 1960. Soils of the flood plain of the Podgornoye raion, Voronezh Oblast', their genesis, composition, properties, and principal methods of their agricultural reclamation and utilization. Author's dissertation for a candidate's degree in agricultural sciences (Voronezhsh. s.-kh in-t). Voronezh. 24 pp.

16. GARKUSHA, I. F. 1960. Preliminary results of soil investigations in the Mogilev Oblast'. Tr. Belorussk. s.-kh. akad. 32 (2):3-19.

17. DIMO, N. A. 1960. Types of soil salinization. Properties and characteristics of soils in the Alazan valley. (Collection of scientific papers). Kiev, Izd. Kiev. un-ta. 177 pp. with illustr. Bibliog. 24 refs.

18. Papers of Soviet soil scientists presented at the VII International Congress of Soil

Science in the U. S. 1960. Moscow. Izd. Akad. Nauk SSSR. 488 pp. Summaries in foreign languages. (Vsesoyuzn. o-vo pochvovedov).

Fifth commission: Gerasimov, I. P. Construction in the USSR of a World Soil Map and associated scientific problems. pp. 275-279.

Ivanova, Y. N. and N. N. Rozov. Classification of soils in the USSR. pp. 280-293.

Kovda, V. A. and Ye. V. Lobova. Project of a 1:6,000,000 soil map of Asia. pp. 294-306.

Ivanova, Ye. N., P. A. Letunov, N. N. Rozov, V. M. Fridland, and S. A. Shuvalov. New scheme for the geographical regionalization of soils in the USSR. pp. 307-311, with map.

Volobuyev, V. R. Problems of the energy of soil formation. pp. 312-317.

Glazovskaya, M. A. Relationship between weathering and soil formation. pp. 318-324.

Vlasyuk, P. A. System of investigations of the soil in the Ukrainian SSR for individual farms. pp. 325-334, with figures and plans.

Mamytov, A. M. Geographical principles and characteristics of soil formation in the Kirgiz SSR. pp. 335-341, with map.

Katz, N. Ya. Bogs and bog provinces in the plains of the temperate zone of the Northern Hemisphere. pp. 342-348, with 2 figures.

Dobrovol'skiy, G. V. Evolution of floodplain soils in the forest and forest steppe zone of the Russian Plain. pp. 349-357.

Yerokhina, A. A. and Ye. L. Lyubimova. Influence of a long period of freezing on soils and vegetation (taking Central Siberia as an example). pp. 358-363.

Fridland, V. M. Red-yellow laterite soils of constantly humid tropical forests. pp. 364-371.

Zonn. S. V. Principal problems and the most important results of the study of the influence of forest vegetation on soils. pp. 372-379.

IVANOV, A. D. 1960. Formation and distribution of loose sand in the Barguzin depression. Drayeved. sb. (Buryat. fil. Geogr. o-va SSSR). pp. 79-90, with maps.

KALASHNIKOV, K. V. 1960. Podzolic soils of the Khanty-Mansiysk national district and the influence of cultivation on their properties. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Mosk. s.-kh. akad. im. Timiryazeva). Moscow. 19 pp.

21. KIM ZUN SEK. 1960. Change in the composition and properties of sod-podzolic forest soils of the western forest steppe of the southern part of Poles'ye during agricultural reclamation. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Ukr. akad. s.-kh. nauk). Kiev. 24 pp.

22. KIRILLOV, M. V. and P. S. BUGAKOV. 1959. Scheme for the regionalization of soils in Krasnoyarsk Province (tundra, taiga, sub-tayga). Part 1. Tr. Krasnoyarsk. s.-kh. in-ta. 3(1):218-231, with maps.

23. KOLKHODZHAYEV, M. K. and A. A. SOKOLOV. 1960. Materials for the study of the soil in Southeastern Kalba. Tr. In-ta pochvovedeniye Akad. Nauk KazSSR. Vol. 2:3-59, with maps. Bibliog. 10 refs.

24. KONNOYKO, M. A. 1960. Genesis and stratification of ridge-depression complexes in upland peat bed in the northwestern regions of the Belorussian SSR. Tr. In-ta torfa Akad. Nauk BSSR. Vol. 9:216-221. Bibliog. 10 refs.

25. KUZNETSOV, A. T. 1960. Climatic characteristics of Kazakhstan. Vopr. geogr. Kazakhstana (Akad. Nauk KazSSR), No. 7:108-135, with maps. Bibliog. 40 refs.

26. KUZNETSOVA, I. V. 1960. Knowledge of microdepressions in the formation of soil in the northern part of the Yergeney and the utilization of artificial microrelief in drought control. Author's summary of his dissertation for a candidate's degree in biological sciences (Mosk. gos. un-t. Biol.-pochv. fak.). Moscow. 19 pp.

27. KUNYAVSKIY, M. P. 1960. Land resources of the Uzbek SSR. Tr. TIIMS (Tashkentsk. in-t inzh. irrig. i mekhanizatsii s. kh).No. 4:38-61, with maps.

28. LAZUKOVA, G. I. 1960. Quaternary deposits in the northwestern part of the West Siberian depression. Tr. Vsesoyuz. neft. i geologorazved. in-ta. No. 158: 92-116. Bibliog. pp. 115-116.

29. LITVINOVA, A. A. 1960. Soils of the lower reaches of the Ili River and outlooks for their agricultural reclamation. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Kazakhsk. gos. s.-kh. in-t). Alma-Ata. 18 pp.

30. Materials on the geomorphology and palaeography of the USSR. (Collection of articles. Responsible editor, V. P. Grichuk). Tr. In-ta geogr. Akad. Nauk SSSR. No. 21. Papers on spore-pollen analysis. Moscow, Izd. Akad. Nauk SSSR. 199 pp. with illustr. and maps.

31. Materials on the geomorphology and palaeography of the USSR. (Responsible editor, B. A. Fedorovich). Tr. In-ta geogr. Akad.

Nauk SSSR. Vol. 24. Origin of sand relief and loess. Moscow, Izd. Akad. Nauk SSSR. 124 pp. with illustr.

32. MIROSHNICHENKO, V. P. 1960. Takyrs as indicators of most recent tectonic movements in the sand deserts of Central Asia. Tr. Labor. aerometodov (Akad. Nauk SSSR). Vol. 9:3-39, with tables. Bibliog. pp. 38-39.

33. NADEZHDIN, B. V. 1960. Conditions of soil formation in the Nyshminsk pine forests in the Sverdlovsk Oblast'. Tr. In-ta biol. (Ural'sk. fil. Akad. Nauk SSSR). No. 19:37-48. Bibliog. p. 48.

34. POPOVA, G. Z. 1960. Relief of the northeastern part of the Central-Kazakhstan low-hill area. Vopr. geogr. Kazakhstana (Akad. Nauk KazSSR). No. 7:35-58, with maps. Bibliog. 9 refs.

35. Soils of Altay Province. 1959. (Responsible editors, N. I. Bazilevich and A. N. Rozanov). Moscow, Izd. Akad. Nauk SSSR. With illustr. 2 sheets of tables, 4 maps. (Akad. Nauk SSSR. Pochv. in-t im. Dokuchayeva i Sovet po izuch. proizvod sil).

36. Soils and measures for their productive utilization in the Frunze kolkhoz, Nezhin rayon, Chernigov Oblast'. 1960. Kiev, Izd. Ukr. akad. s.-kh. nauk. 62 pp.

37. Soils of the Kazakh SSR. 1960. 16 vol. (Chief editor, A. I. Bezsonov). In-t pochvovedeniya Akad. Nauk KazSSR. Alma-Ata. Izd. Akad. Nauk KazSSR. No. 1 — Fedorin, Yu. V. Soils of the North Kazakhstan Oblast'. 175 pp., with maps pp. 172-174. No. 2 — Pachikina, L. I., and M. I. Rubinshteyn. Soils of the Kokchetav Oblast'. 137 pp. with illustr. and maps. Bibliog. pp. 132-134.

38. Soils of the Mazhit Gafuri kolkhoz and ways of rationally utilizing them. 1960. S. N. Taychinov, editor. (Akad. Nauk SSSR, Bashkir, fil. In-t biol.). Ufa. 126 pp. with illustr.

39. RATNIKOV, A. I. 1960. Soils of the Tula Oblast'. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Mosk. s.-kh. akad. im. Timiryazeva). Moscow. 19 pp.

40. RYNKE, I. N. 1960. Soils of the Alar rayon, Irkutsk Oblast', and their agricultural utilization. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Irkutsk. s.-kh. in-t). Irkutsk. 23 pp.

41. RYCHAGOV, G. I. and O. K. LEONT'YEV. 1960. The major stages in the development of the relief of the flat part of the Eastern Cis-Caucasus. Izv. Akad. Nauk SSSR. Ser. geogr. No. 4:75-82, with maps. Bibliog. pp. 81-82.

42. SARKISYAN, S. S. 1960. Soils of the kolkhozes of the Tallin rayon in the Armenian SSR from a zonal point of view. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Armyansk. s.-kh. in-t). Yerevan. 24 pp.

43. SEDLUKHO, N. YA. 1960. Certain regular patterns in the change of sod-podzolic soils depending on the degree of their cultivation. Tr. Belorussk. s.-kh. akad. 32(2): 20-34, with tables, Bibliog. 43 refs.

44. STUPINA, N. M. 1960. Geomorphology of the Trans-Urals forest steppe. Tr. Inta biol. (Ural'sk. fil. Akad. Nauk SSSR). No. 19:5-22, with maps.

45. TETYUKHIN, G. F. 1960. Stratigraphy of loess-like materials in the Tashkent area. Uchen. zap. (Sredneaziatsk. n.-i. in-t geol. i mineral. syr'ya). No. 3:33-38.

46. KHARCHENKO, B. 1960. Soil map and the improvement in farming. Kolkhoz. proizvodstvo. No. 8:15-17.

47. CHZHAN TSZU-SI. 1960. Brown forest soils in southern Crimea and the northeastern portion of the Ukrainian Carpathians and their properties. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Ukr. s.-kh. akad.). Kiev. 16 pp.

48. CHULTUROV, SH. M., R. DZHANPEISOV, A. A. SOKOLOV, and K. SH. FAIZOV. 1960. Soil-climatic conditions in the Pavlodar Oblast' and its agricultural regionalization. Vestn. s.-kh. nauki, Alma-Ata. No. 5:3-15. Summary in the Kazakh Language.

49. SHKVARUK, N. M. and S. YE. SATATYY. 1960. Natural conditions of the Uman' rayon (Cherkassk Oblast'). Sb. anuchn. tr. (Umansk. s.-kh. in-t). No. 12:19-37. Bibliog. 6 refs.

50. ARAKERI, H. R., and others. 1959. Soil management in India. London, 584 p.

51. ARANY, A. 1960. Die Klassifizierung der Ungarischen Alkali-(Szik)-Böden. Albrecht-Thaer-Arch. 4, s. 23-26. d. Ref.: Soils and Fertilizers. N 4, p. 1630.

52. AUBERT, G. 1960. The phosphoric acid of the soils of tropical regions. Bull. docum. Assoc. internat. fabricants superphos. No. 27, p. 3-14.

53. BURING, P. 1960. Soils and soil conditions in Iraq. Bagdad. 322, p.

54. Biological studies of some tussock-grass land soils. 12-17, N. Z. J. Agric. Res. 1960. 3 N 2, p. 197-243.

55. KOWALOWSKI. A. 1959. Genetyczna klasyfikacjy gieb polski. Roczn. gleboznawcze, 7 c. 3-9.

56. LEBUGHE, Y. van PÉE W. 1960. Le dosage molybdène par voie microbiologique

dans les soils sableux du Kalahari de la région de Léopoldville. Bull. Agric. Congo Belge, 51, p. 739-51.

57. MUSIEROWICZ, A. 1959. Zarvs systematyki gleb Polski. Zesz. Problem. Postep. Nauk. rol. N 16, c15-61.

58. RAESIDE, J. D. and other. 1959. Soils and agriculture of part of Geraldin County, New Zealand. DSIR (N. Z.) Soil Bur. Bull. 13, 65 p.

59. SCHILLER, H. und ANDERE. 1959. Der Nährstoffzustand der Böden Oberösterreichs. Festschr. sechsigjähr. Best. Landw. — chem. Bundes — vers Anst. Linz, p. 54-1. Ref.: Soils and Fertilizers N, 5, r, 1928.

60. SCHNEPPE, F. 1960. Die Ertragssteigerung auf den leichten Böden der Lüneburger Heide. Agrargeschichte u. Agrarsoziolog. 8, Ht. I, s, 14-22.

61. WILSON, K. 1960. The time factor in the development of dune soils at South Haven Peninsula, Dorest. J. Ecol. 48, N 2, p. 341-60. Bibl. 18 ref.

62. YADAR, J. S. 1960. P. Soils of the dry zone of India. Forester. No. 5, p. 274-95. Bibliog. 10 ref.

SOIL MINERALOGY

63. GORBUNOV, N. I. and SUN DA-CHEN. Formation of secondary minerals during the first state of soil formation. In the book: Papers of Soviet soil scientists presented at the VII International Congress of Soil Science in the U. S. Moscow, Izd. Akad. Nauk SSSR. pp. 453-460 with illustr. Summary in English.

64. MINASHINA, N. G. Micromorphological investigations of loess and its changes during soil formation. Ibid., pp. 465-475, with 8 fig. Bibliog. 9 refs. Summary in English.

65. FEOFAROVA, I. I. Micromorphological characterization of clay substances in soils. Ibid. pp. 461-465, with 11 figs. Summary in English.

66. YARILOVA, YE. A. and YE. N. PARFENOVA. Problem of the nature of clay minerals in the colloidal fractions of soils. Ibid. pp. 476-482. Summary in English.

67. BARSHAD, I. 1960. X-ray analysis of soil colloids by a modified salted paste method. Proc. 7th nat. Conf. Clays. 5 p. 350-64.

68. HEY, M. H. 1960. Glottalite is chabazite. Mineral. Mag. N 248, p. 421, 32.

69. MEYER, B., E. KALK. 1959. Die Mineralbestimmung in Tonfraktionen des Bodens. mit Hilfe der Phasenkontrast und Grenzdunkelfeldmikroskopie. Landwirtsch. Forsch. Ht. I, S. 3-12.

70. SCOTT, A. D. and others. 1960. Removal of fixed ammonium from clay minerals by cation exchange resins. Nature. N 4715 p. 792.

71. STEPHEN, I. 1960. Clay orientation in soils Sci. Progr. Land. 48, p. 322-30.

PHYSICAL PROPERTIES OF SOILS AND METHODS OF INVESTIGATION

72. AGAYEV, B. M. 1960. Study of the physical properties of soils in Azérbaydzhan. Izv. Akad. Nauk AzSSR. Ser. biol. i med. n. No. 2:109-113.

73. AGASHKIN, YU. N. 1960. Investigations of snow melting with radioactive isotopes. Izv. Akad. Nauk SSSR. Ser. geogr. No. 4:117-121.

74. ALEKSIN, A. A. 1960. Certain problems of the aeration regime and the ground waters of arid regions. Sov. geol. No. 7:95-102. Bibliog. 9 refs.

75. GAO CHZHEN-MIN'. 1960. Water permeability of soil and methods of regulating it. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Poch. in-t im. Dokuchayeva). Moscow 23 pp.

76. Papers of Soviet soil scientists presented at the VII International Congress of Soil Scientists in the U. S. 1960. Moscow, Izd. Akad. Nauk SSSR. Summaries in foreign languages.

First commission — Soil physics. pp. 5-80.

Kachinskiy, N. A. Soil classification according to texture for agronomical purposes. pp. 5-14.

Verigo, S. A., S. B. Mastinskaya, and L. A. Razumova. Water regime of soils and the moisture available to grain crops in the USSR. pp. 15-20.

Alpat'yeva, A. M. Complex method of determining the excess and deficiency of soil moisture for plants and its use in practical agriculture. pp. 21-26.

Nerpin, S. V. and A. I. Kotov. Rheological properties of soil moisture and their consideration in the theory of moisture conductivity. pp. 35-40 with 4 figs.

Popov, O. V. Soil air during the infiltration of water into the soil. pp. 35-40 with figure.

Dolgov, S. I. Characteristics of the water regime of soils in the steppe regions of Altay Province and a system of measures for overcoming aridity in these regions. pp. 41-53 with 5 figs.

Chudnovskiy, A. F. Study, prediction, and regulation of the thermal regime of soil. pp. 52-59.

Vershinin, P. V. Soil structure and ways of regulating it. pp. 60-63.

Ryzhov, S. N. and N. I. Zimina. Physical ripeness of soils of the major groups in the irrigated zone of Central Asia. pp. 66-73.

Gussak, V. B. Certain new data on the mechanics of the interaction between phases in the soil. pp. 73-80, with 6 figs.

77. YEFREMOVA, T. N. 1960. Forecasting the natural regime of the ground water level. Razvedka i okhrana nedr. No. 8:38-45.

78. ZHELTAYA, N. N. 1960. Water regime of soils under conditions of depression farming. Tr. Tsentr. in-ta prognozov. No. 98:24-38.

79. IVANOV, V. V. 1960. Origin and classification of recent hydrothermal springs. Geokhimiya. No. 5:443-450. Bibliog. 45 refs.

80. Instructions on the determination of soil moisture for the selection of better irrigation periods for cotton and other agricultural crops. Approved June 9, 1960. M-vo s. kh. UzSSR. Tashkent. 7 pp. In the Uzbek and Russian languages.

81. KIRICHENKO, G. T. 1960. Problem of reflecting light by the soil. Tr. (Dneprovsk. s.-kh. in-t). Vol. 8:87-89.

82. KONTORSHCHIKOV, A. S. 1960. Method of agricultural-climatic calculations of soil moisture in the autumn. Tr. Tsentr. in-ta prognozov. No. 98:39-47. Bibliog. 21 refs.

83. KRYUGER, G. P. 1960. Ground-water regime under rice plantations on solonchaks. Uzbeksk. geol. zh. No. 3:47-54. Bibliog. 6 refs. Summary in the Uzbek language.

84. KUZNETSOV, A. T. and V. P. TKACHUKH. 1960. Problem of the study of the snow cover in Kazakhstan. Vopr. geogr. Kazakhstana (Akad. Nauk KazSSR). No. 7:177-183, with maps. Bibliog. 7 refs.

85. MALYSHEV, F. A. Theoretical basis of the penetration of solid peat particles from the hydromass into the soil and soil material. Tr. In-ta torfa Akad. Nauk BSSR. Vol. 9:177-183. Bibliog. 9 refs.

86. PUKHTINSKIY, YU. YE. 1960. Change in soil temperature under the influence of irrigation and cultivation. Sadovodstvo. No. 7:35-37.

87. ROMANOV, V. V. 1960. Change in the water balance of bogs in dry and wet years. Tr. Gidrol. in-ta. No. 89:5-36. Bibliog. 7 refs.

88. ROMANOVA, YE. A. 1960. Relationship between vegetation, the upper layers of peat beds, and the water regime of upland bogs in the Northwest. Tr. Gidrol. in-ta No. 89:92-122. Bibliog. 32 refs.

89. Results of investigations on runoff formation and the evaporation regime. (According to materials of the Valday Hydrological Scientific-Research Laboratory). Tr. Gos. gidrol. in-ta. No. 76. Leningrad, Gidrometeoizdat. 179 pp. with illustr.

90. TRAPEZNIKOV, F. F. 1958. Physical properties of soil materials in the Kopetdag piedmont valley. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Stalinabadsk. s.-kh. in-t). Ashkhabad. 16 pp.

91. KHORLIKOV, V. M. 1959. Certain characteristics of the heat exchange in irrigation channels. Tr. Kazakhsk. s.-kh. in-ta. Vol. 6:226-232. Bibliog. 9 refs.

92. CHUDNOVSKIY. 1960. Influence of the variable nature of the thermophysical characteristics of soils along their profiles on soil temperature. Inzh-fiz. zh. 3(7):51-59.

93. YAO SYAN-LYAN. 1960. Comparative study of certain basic methods of the particle-size analysis of soil. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Pochv. in-t im. Dokuchayeva). Moscow. 23 pp.

94. ADAMS, R. S., R. ELLIS. 1959. Some physical und chemical Methods zur kolorimetrischen Bestimmung der Bodenatmung im Laboratoriumsversuch. Z. Pflanzenernähr., Düng., Bodenkunde. 87 (132), Ht. 2, S. 143-56.

95. BIGGAR, J. W. and others. 1960. Some aspects of the kinetics of moisture flow into unsaturated soils. Soil sci. Soc. America Proc. n 2, p. 81-85.

96. BOREL, G. A. 1960. Portable instrument for measuring soil moisture. Netherlands J. agric. Sci. 8, p. 132-38.

97. BOUYOUCOS, G. 1960. Measuring soil moisture tension. Agric. Engng. Mich. 41, p. 40-41.

98. COPPER, D. J. and others. 1960. Note on an apparatus for controlling soil temperatures. Canad. J. Soil Sci. No. 1, p. 105-107.

99. DAVIDSON, J. M., D. D. EVANS. 1960. Turbidimeter technique for measuring the stability of soil aggregates in a water-glycerol mixture. Soil Sci. Soc. America Proc. No. 2, p. 75-79.

100. FADDA, N. R. 1960. The use of electrical resistance units for the study of soil moisture change and irrigation requirements in the Sudan Gezira. Empire Cotton Grow. Rev. 37, p. 118-30.

101. FRERCKS, W., D. PUFFE. 1959. Vergleich-

ende Untersuchungen zwischen der Bodenatmung und der CO_2 Produktion von Moorböden — Z. Pflanzenernähr., Düng., Bodenkunde. 87 (132), Ht. 2, S. 108-18.

102. JANSE, A. P., G. H. BOLT. 1960. The determination of air-permeability of soils. Netherl. J. agric. Sci. 8, p. 124-31.

103. Measurement of soil humidity by radioactive methods. Current Sci. 29, p. 127.

104. MERRIAM, R. A. 1960. Moisture sampling in wildland soils with a neutron probe. Iowa St. Coll. J. Sci. 34, p. 641-47.

105. MONTENS, A. 1960. Untersuchungen von Fliessvorgangen mit Hilfe von radioaktiven Isotopen. Wasser und Boden. Ht. 4, S. 113-15.

106. RID, H. 1959. Methode der Krümelstabilitätsmessung durch Schallschwingungen. Z. Pflanzenernähr., Düng., Bodenkunde, 87 (132), Ht. 3, S. 216-23.

107. RID, H. 1960. Über eine Feldmethode zur Messung der Bodendurchluftung. Z. Pflanzenernähr., Düng., Bodenkunde, 88, Ht. 3. S. 227-31.

108. SCHARPENSEEL, H. W., H. GEWEHR. 1960. Studien zur Wasserbewegung im Boden mit Tritium-Wasser. Z. Pflanzenernähr., Düng., Bodenkunde, 88, Ht. I, S. 35-49.

109. SHAW, M. D., W. O. ARBLE. 1959. Bibliography on methods for determining soil moisture. Pensylvania. 152 p.

110. WILCOX, J. C. 1960. A statistical comparison of laboratory methods of determining the permanent wilting point of soil. Canad. J. Soil Sci. 1960. N 1, p. 111-12.

SOIL CHEMISTRY AND METHODS OF ANALYSIS

111. BLAGOVESHCHENSKAYA, G. I. 1960. Problem of the determination of potassium by the cobalti-nitrite method. Tr. Kazansk. khim-tekhnol. in-ta. No. 29: 36-39. Bibliog. 27 refs.

112. GYUL'AKHMEDOV, A. 1960. New, rapid methods of determining microelements in calcareous soils. Sots. s. kh. Azerbaydzhana. No. 7:55-56.

113. Papers of Soviet soil scientists presented at the VII International Congress of Soil Science in the U. S. 1960. Moscow, Izd. Akad. Nauk SSSR. Summaries in foreign languages. Second commission — Soil chemistry. pp. 83-151.

Peyve, Ya. V. Content of microelements (B, Cu, Mn, Zn, Mo, Co) in the soils of the USSR and the effectiveness of microfertilizers. pp. 83-90.

Gulyakin, I. V. and Ye. V. Yudintseva. Agricultural chemistry of fragmentary elements. pp. 92-99.

Polyakov, Yu. A. Determination of the thermodynamic characteristics of the exchangeable adsorption of calcium and strontium ions in soils. pp. 100-105.

Mel'nikova, M. K., L. S. Dotsenko, and A. D. Kudelya. Possibilities of decreasing the uptake of radioactive strontium by plants from the soil. pp. 106-109.

Remezov, N. P. Biological cycle of elements, its role in soil formation and ways of studying it. pp. 110-115.

Pershina, M. N. and M. Ye. Yakovleva. Biological cycle of ash substances in the dry steppe zone of the USSR. pp. 116-123.

Smirnova, K. M. Study of the composition of lysimeter waters under a spruce forest. pp. 124-128.

Aleksandrova, L. N. Organo-mineral compounds and organo-mineral colloids in the soil. pp. 130-136.

Kaurichev, I. S., Ye. V. Kulakov, and Ye. M. Nozdrunova. Nature of complex organic iron compounds in the soil. pp. 137-142.

Nikonov, M. N., S. S. Dragunov, and S. I. Pershin. Chemical composition of organic substances in the ash portion of peats in the USSR. pp. 144-151.

114. KOVALEVA, YE. L. 1960. Problem of the change in pH, in the oxidation-reduction potential and available iron in the soils of the Lenkoran zone in relation to various degrees of wetting. Dokl. (Akad. Nauk AzSSR). 16(4):371-376. Summary in the Azerbaydzhan language.

115. KULIKOV, N. V. 1960. Influence of Na-ethyllenediaminetetraacetic acid on the behavior of radioactive cobalt in the soil-plant system. Dokl. Akad. Nauk SSSR. 133(3): 698-701. Bibliog. 17 refs.

116. LAGUTINSKAYA, N. A. 1960. Salt regime of irrigated soils under crop rotation in a small grape-plant nursery. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Odessk. s.-kh. in-t). Odessa. 16 pp.

117. LYSIKOVA, N. N. 1960. Problem of the total composition of the mineral portion of takyrs and takyr soils. Tr. TIIIMSKH (Tashkentsk. in-t inzh. irrig. i mekhanizatsii s.-kh.). No. 14:62-74. Bibliog. p. 74.

118. LUKASHEV, K. I. and L. G. FEDULOVA. 1960. Chemical composition of loess-like deposits in the Rutkovichi and Dubrovno regions of the BSSR. Dokl. akad. Nauk BSSR. 4(7):298-306.

119. STREYNA, I. P. 1960. Determination of iodine and bromine in plants and soils. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Latv. s.-kh. akad.). Riga. 29 pp.

120. CHERNIKOVA, T. N. 1960. Theoretical bases for the determination of acidity. Tr. Vsesoyuzn. n.-i. in-ta udobr. i agropochvoved. No. 34:133-138.

121. AUNG KHIN, G. W. LEEPER. 1960. Modifications in Chang and Jackson's procedure for fractionating soil phosphorus. Agrochimica. 4 N 3 p. 246-54.

122. BECKER, M., M. DREWS. 1960. Untersuchungen zur kolorimetrischen P_2O_5 Bestimmung mit der Vanadat-Molibdat — Methode im Hinblick auf die Eignung verschiedener Messgeräte. Albrecht-Thaer-Arch. 4, S. 120-30.

123. BÖNIG, O., P. JUNGMANN. 1960. Eine Apparatur zur Anreicherung von Mikronährsteffen. Landwirtsch. Forsch. 13, N 1, S. 62-64.

124. CANDUSSIO, R., M. V. ROMANIN. 1960. Ricerche sul fosforo "assimilabile" dei terreni ferrettizzati. Comparazione di metode chimici di determinazione della anidride fosforica "assimilabile". Ann. sperim. agrar., N. 14, p. 211-31.

125. ERNST, J. W., H. F. MASSEY. 1960. The effects of several factors on volatilization of Ammonia, formed from urea in the soil. Soil Sci. Soc. America Proc. No. 2, 87-90.

126. FINE, L. O. and others. 1959. A study of the sodium adsorption ratio and residual sodium carbonate concepts of irrigation waters as they affect exchangeable sodium of soil under semi-arid conditions. Soil Sci. Soc. America Proc. 23, No. 4, p. 263-66.

127. HARTGE, K. 1960. Die Auswertung von pF Kurven. Z. Pflanzenernähr., Düng., Bodenkunde. 88, Ht. 3, S 221-27.

128. HENDERSON, J. H. M. 1960. Influence of hydrogen ion concentration and autoclaving on gibberellin. Nature. N 4713, p. 828-29.

129. HOVLAND, D., A. C. CALDWELL. 1960. Potassium and magnesium relationships in soils and plants, Soil Sci. N 2, p. 92-96.

130. Influence of K and Cs on release of Ce^{137} from three soils. Soil. Sci. 1960, 89, N 3, 167-76.

131. KHAN, D. H. 1960. A study of the effect of colloidal silica in peptising iron oxide with reference to red brown soil formation on limestone. J. Sci. Food and Agric. 1960. N 3, p. 133-36. Bibl. 12 refs.

132. LITYNKS, T., T. CURYO. 1959. The calculation of lime requirement from the hydrolytic acidity of soil. Zesz. nauk wyz. Szrol. rol. Krakow Rol. 1959. N 3, p. 61-71.

133. MOSKAL, S., T. BARSZCZAK. 1959. Determination with the aid of P^{32} of phosphates added to the soil. Roczn. gleboznawcze. 7, p. 45-53.

134. MOSKAL, S., T. BARSZCZAK. 1959. Determination with the aid of P^{32} of sorption of phosphates during preparation of soil solution. Roczn. gleboznawcze. 7, p. 55-63.

135. MUSIEROWICZ, A., H. KROL. 1959. Studia nad kompksem sorpayjnym i zawartoscia kationow wymiennych w wazniejszych glebach wojewodztwa lodzkiego. Roszn. gleboznawcze. 8, c. 81-108.

136. NIGRO, C. 1960. Sulla determinazione dell'-azoto mineralizzabile nel terreno. Ann. sperim. agrar. p. 197-209.

137. PRAFF, C., H. ROTH. 1959. Zur Düngung mit Mikronährstoffen, Landwirtsch. — Forsc 12, Ht. 4, s. 231-39.

138. THORNTHWAITE, C. W. and others. 1960. Movement of radiostrontium in soils. Science, 131, N. 3406, p. 1015-19.

139. TUCKER, B. M. 1960. The measurement of the ionexchange properties of soils. CSIRO Soil Publ. 15, 40 p. Ref.: Soils and Fertilizers. No. 5, p. 1985.

BIOLOGY AND MICROBIOLOGY OF SOILS

140. BELYAYEV, G. N. 1960. Influence of the prolonged application of fertilizers on the microflora of sod-podzolic, coherent-sandy soil in relation to the cultivation of field crops. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Permsk. s.-kh. in-t). Perm', Solikamsk. 17 pp.

141. BELYAYEV, G. N. 1960. Microflora of sod-podzolic sandy soils in relation to the change in their fertility under the prolonged use of fertilizers. Agrobiologiya. No. 4:603-610. Bibliog. 16 refs.

142. VOROSHILOVA, G. A. 1960. Microflora of the rhizosphere of the apple tree along the roots. Preliminary report. Sb. nauchn. trud. (Umansk. s.-kh. in-t). No. 12:203-205. Bibliog. 8 refs.

143. GEL'TSER, F. YU. 1960. Humus — its formation and properties. Author's summary of his dissertation for a doctor's degree in biological sciences. (Mosk. s.-kh. akad. im. Timiryazeva). Moscow. 25 pp.

144. GUTSEVICH, S. A. 1960. Characteristics of the microflora in the steppes of the Crimean peninsula. Vestn. Leningr. un-ta. No. 15, Ser. biol. No. 3:23-34. Bibliog. pp. 33-34.

145. Papers of Soviet soil scientists presented at the VII International Congress of Soil Science in the USSR. 1960. Moscow, Izd. Akad. Nauk SSSR. Summaries in foreign languages. (Vsesoyuz. o-vo pochvovedov).

Third commission: Kononova, M. M., I. V. Aleksandrova, and N. P. Bel'chikova. Biosynthesis of humic substances and their transformation during soil formation. pp. 155-160, with illustr.

Mishustin, Y. N., D. N. Nikitin, and M. Ochilova. Microorganisms decomposing the humic acid of the soil. pp. 161-168.

Krasil'nikov, N. A. Importance of microorganisms in the toxicity of the soil. pp. 169-176, with fig. Berezova, Ye. F. Biological processes of the transformation of mineral forms of phosphates in the soil. pp. 177-183, with fig.

Runov, Ye. V. Influence of woody forest plants on the soil microflora. pp. 184-189.

Shtina, E. A. Zonality in the distribution of associations of soil algae. pp. 190-194.

146. ZINOV'YEVA, KH. G. 1960. Interrelationship between the *Azotobacter* and higher plants. Author's summary of her dissertation for a doctor's degree in biological sciences (Akad. Nauk USSR. Otd. biol. nauk). Kiev. 43 pp.

147. Study of the influence of soil tillage on microbiological processes. Papers presented at a conference in Leningrad in February 1958. 1960. Tr. In-ta mikrobiologii Akad. Nauk SSSR. No. 7. Moscow, Izd. Akad. Nauk SSSR. 336 pp. with illustr.

148. KRAVTSOV, P. V. 1960. Influence of electricity on the development of nitrifying bacteria, the intensity of nitrification, and the accumulation of nitrates in the soil. Byul. Tsentr. genet. labor. im. Michurina. No. 9-10:65-69.

149. KURBATOVA-BELIKOVA, N. M. 1960. Development of microorganisms in peat depending on its type and its degree of decomposition. Tr. In-ta torfa Akad. Nauk BSSR. Vol. 9:222-230.

150. MARGO, A. A. and G. YA. DOROBOVA. 1960. Nitrogen-fixing ability of smooth and rough *Azotobacter* variants. Tr. Belorussk. s.-kh. akad. 32(2):102-111. Bibliog. 8 refs.

151. MARGO, A. A., M. A. PESHKOVA, A. V. KRASIKOVA, and others. 1960. Effectiveness of azotobacterin against various backgrounds of organic and mineral fertilizers, taking into account ecological conditions which influence the development of the *Azotobacter*. Tr. Belorussk. s.-kh. akad. 32(2):96-101. Bibliog. 6 refs.

152. NIKITIN, D. I. 1960. Decomposition of humic acids in the soil by microorganisms. Izv. Akad. Nauk SSSR. Ser. biol. No. 4: 618-625. Bibliog. pp. 624-625.

153. PIKUSIN, A. G. 1960. Microflora of subtropical soils in the Lenkoran zone. Author's summary of his dissertation for a candidate's degree in biological sciences (Akad. Nauk ArmSSR. Otd. biol. nauk). Baku. 25 pp.

154. PIKUSIN, A. G. 1960. Microflora of soils in the Lenkoran subtropical zone. Izv. Akad. Nauk AzSSR. Ser. biol. i med. nauk. No. 3:149-159. Bibliog. 8 refs. Summary in the Azerbaydzhan language.

155. POSHON, ZH. and G. BARZHAK. 1960. Soil microbiology. Translation from the French with an introduction by A. A. Imshenetskiy. Moscow, Izd. in. lit. 560 pp. with illustr.

156. ROYZIN, M. B. 1960. Microflora of rocks from primitive soils in the high Arctic desert. Botan. zh. 45(7):997-1008, p. Bibliog. 1007.

157. RYBKINA, N. A. 1960. Distribution of anaerobic nitrogen-fixing bacteria in crop rotation fields. Vestn. s.-kh. nauk. No. 7:137-139. Bibliog. 10 refs.

158. RUNOV, YE. V. and YE. N. ZHDANNIKOVA. 1960. Microflora of the rhizosphere of birch and spruce on various soils of the Central Tayga in the Vologda Oblast'. Soobshch. laboratorii lesovedeniya (Akad. Nauk SSSR). No. 2:69-79. Bibliog. p. 79.

159. SHINKAREVA, T. A. 1960. Change in the microflora of decomposing peat-forming plants. Tr. In-ta torfa Akad. Nauk BSSR. Vol. 9:240-253. Bibliog. 9 refs.

160. SHINKAREVA, T. A. 1960. Decomposition of peat-forming plants introduced into a peat bed. Tr. In-ta torfa Akad. Nauk Bssr. Vol. 9:231-239. Bibliog. 9 refs.

161. DOMSCH, K. A. 1960. Das Pilzspektrum einer Bodenprobe. 2. Nachweis physiologischer Merkmale. 3. Nachweis der Einzelpilze. Arch. Mikrobiol. 35, a. 310-39.

162. KROLL, W., B. MEYER. 1959. Die charakterisierung von Humusformen durch Siebanalyse und mikromorphologische Untersuchung am Beispiel einer Bodenserie auf mittlerem Buntsanstein bei Göttingen. Landwirtsch. Forsch. 12, Ht. I, s. 12-17.

163. MISTERSKI, W., W. LOGINOW. 1959. Investigations on some physical and chemical properties of humic acids. Roczn. nauk roln. 79 A, oc. 743-70.

164. RERABEK, J. 1960. Humic acid interactions in the grown process. Biol. Plant, 2, p. 88-97.

165. SCHMITTHENNER, A. F., L. E. WILLIAMS. 1960. Soil moids — friend or foe? Crops

and Soils. 12, N 6, p. 10-11, 18.

166. SKINNER, F. A. 1960. The isolation of anaerobic cellulose-decomposing bacteria from soil. J. Gen. Microbiol. No. 2, p. 539-54. Bibliog. 16 r.

167. SMIDOVA, M. 1960. The influence of humic acids on the respiration of plant roots, Biol. Plant, 2, p. 152-64.

168. SPRINGER, U. 1960. Die Wirkung verschiedener organischer Dünger auf den Humuszustand des Bodens Bayer Landwirtsch. Jamb. 37, s. 3-39. Ref.: Soils and Fertilizers. N 4, p. 1798.

SOIL FERTILITY, FERTILIZERS, AND TILLAGE

169. AVDONIN, N. S. 1960. Increasing the fertility of acid soils. Moscow, Sel'khozgiz. 240 pp. with illustr. Bibliog. pp. 230-239.

170. Agricultural-chemical investigations in the Azerbaydzhan SSR. 1960 (Collection of papers. Editor, D. M. Guseinov). Tr. In-ta pochvoved. i agrokhimii (Akad. Nauk AzSSR). Vol. 9, Baku. 157 pp. Summaries in the Azerbaydzhan language.

171. BUROV, D. I. 1960. Agricultural requirements of soil tillage. Kuybyshev, Kn. izd. 120 pp. with illustr.

172. BEREDCHENKO, YU. P. 1960. Agronomical characterization of soils in the Krasnodar agricultural region. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Pochv. in-t im. Dokuchayeva). Moscow, 21 pp. with illustr.

173. GAYNUTDINOV, M. Z. 1960. Problem of the cultivation of light-gray forest-steppe soils in the northern part of the Tatar ASSR. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Omskiy s.-kh. in-t). Kazan'. 20 pp.

174. GILLIS, M. B. 1960. Methods of applying fertilizers to agricultural crops under conditions of the western regions of the Ukrainian SSR. Author's summary of his dissertation for a doctor's degree in agricultural sciences (Mosk. s.-kh. akad. im. Timiryazeva). Moscow. 31 pp.

175. GLAZKOV, P. N. 1960. Effectiveness of various forms of phosphorous fertilizers in grass-arable rotation on coarse textured sod-podzolic soils. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Nauchn. in-t po udobr. i insektofung.). Moscow. 18 pp.

176. GOLIKOVA, O. P. 1960. Influence of various forms of potassium fertilizers on the natural radioactivity of plants. Author's summary of her dissertation for a candidate's degree in biological sciences (Akad. Nauk USSR, In-t botaniki). Kiev. 14 pp.

177. GUMAROVA, KH. F. 1960. Water regime of cotton on saline soils. Author's summary of her dissertation for a candidate's degree in biological sciences (In-t genetiki i fiziol. rasteniy. Akad. Nauk UzSSR). Tashkent. 20 pp.

178. DEREVITSKIY, N. F. 1960. Methodological problems of field experimentation. Kishinev. 143 pp. (Moldav. fil. Akad. Nauk SSSR, Pochv. in-t im. N. A. Dimo). Bibliog. 43 refs.

179. Papers of Soviet soil scientists presented at the VII International Congress of Soil Science in the U. S. 1960. Moscow Izd. Akad. Nauk SSSR. Summaries in foreign languages. Fourth commission:

Turchin, F. V., Z. N. Beresneva, I. A. Koritskaya, G. G. Zhidkikh, and G. A. Lobovikova. Transformation of nitrogen in the soil according to the results of investigations by means of the isotope N^{15}. pp. 197-201.

Magnitskiy, K. P. Results of long-term experiments with magnesium fertilizers. pp. 202-207.

Neunylov, B. A. Oxidation-reduction processes in the soils of the rice field of the Far East and their importance in the nutrition of rice. pp. 208-214.

Peterburgskiy, A. V. Change in the form of potassium in acid sod-podzolic soil under the prolonged application of potassium fertilizers and in relation to the characteristics of the crops being fertilized. pp. 215-222.

Gromyko, I. D. and Ye. V. Kulakov. Change in the physical-chemical and biological properties of virgin chernozems in Northern Kazakhstan under agricultural utilization. pp. 223-229.

Yegorov, V. Ye. A half-century experiment in the use of fertilizers in crop rotation. pp. 230-235.

Grinchenko, A. M. and Din Zhuysin. Influence of prolonged agricultural cultivation on the dynamics of humus, nitrogen, and phosphorus in the soils of the southern part of the Ukrainian SSR. pp. 236-242.

Kedrov-Zikhman, O. K. Influence of microelements on plants in relation to the liming of acid sod-podzolic soils. pp. 243-247.

Katalymov, M. V. Causes for the decrease in the availability of soil boron to plants as a result of soil liming. pp. 246-255.

Sokolov, A. V. Method of determining the amount of soluble and easily available phosphates in the soil by means of radioactive phosphorus (P^{32}). pp. 256-260.

Karpinskiy, N. P., V. B. Zamyatina, and

N. M. Glazunova. Available soil phosphorus and its uptake by plants. pp. 262-269.

Tserling, V. V. Diagnosis of the requirement of fertilizers by plants. pp. 268-272.

180. Trans-Caucasian Conference on Agricultural Chemistry, 2d 1959. (Trudy Akad. Nauk ArmSSR. Labor. agrokhimii). Yerevan, Izd. Akad. Nauk ArmSSR. (Published 1960). 195 pp. with illustr.

181. ZIGANSHIN, A. 1960. Problems of the increase of the fertility of sod-podzolic soils. S. kh. Tatarii. No. 6:43-45.

182. ZUYEV, L. A. 1960. Plant nutrition and soil properties. Tr. Vessoyuz. n.-i. in-ta udobr. i agropochvoved. No. 34:187-195.

183. IVANOV, P. K., M. F. BOGACHEV, and M. S. POSTNOV. 1960. Effectiveness of plowing chernozem with and without a moldboard. S. kh. Povolzh'ya. No. 7: 32:36.

184. KARDINALOVSKAYA, R. I. 1960. Transformation of potassium, applied with fertilizers, in the soil and its utilization by plants. Author's summary of her dissertation for a candidate's degree in agricultural sciences (Ukr. akad. s.-kh. nauk). Kiev. 20 pp.

185. KATALYMOV, M. V. 1960. Microelements and their role in increasing yield. 2d ed. Moscow, Goskhimizdat. 76 pp. with illustr.

186. KORABLEVA, L. I. 1960. Fertilization of flood-plain lands. Moscow, "Mosk. rabochiy." 22 pp. with illustr.

187. KOROVIN, A. I. 1960. Influence of low soil temperature on plants under conditions of the North. Author's summary of his dissertation for a doctor's degree in biological sciences (In-ta fiziol. rasteniy i In-t biol. Krel. fil Akad. Nauk SSSR). Moscow-Petrozavodsk. 40 pp.

188. KRETOVICH, V. L., Z. G. YEVSTIGNEYEVA, and K. B. ASEYEVA. 1960. Assimilation of tagged ammonium by the root system in the soil. Biokhimiya. 25(3):476-481. Bibliog. 16 refs.

189. KULIKOV, G. P. 1960. Stubble treatment of leached chernozems. S. kh. Povolzh'ya. No. 7:29-32.

190. LITVINOV, P. I. 1960. Use of tagged atoms in the study of the intensity of regeneration of grape roots and establishment of the connection between the roots and shoots. Vinodeliye i vinogradarstvo SSSR. No. 5:37-40.

191. NARIYANTS, M. R. 1960. Regime of cotton irrigation on the meadow-bog soils of the Chirchik River valley. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Tashkent. s.-kh. in-t). Tashkent. 24 pp.

192. NARTSISSOV, V. P. 1958. System of agriculture on gray forest soils of the right bank of the Middle Volga region. Author's summary of his dissertation for a doctor's degree in agricultural sciences (Mosk. s.-kh. akad. im. Timiryazeva). Gor'kiy. 40 pp.

193. OLOVYANNIKOV, I. N. 1960. Influence of mineral fertilizers on the grass in natural oak stands. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 47:61-70.

194. OL'KHOVSKIY, L. G. 1960. Method of investigating the root system of sugar beet, corn, and other crops. Sb. nauchn. tr. (Umansk. s.-kh. in-t). No. 12:232-334. Bibliog. 12 refs.

195. PELIPETS, V. A. 1960. Application of small amounts of gypsum to agricultural crops on the solonetzic soils of the Ukraine. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Khar'kov. s.-kh. in-t im. Dokuchayeva). Khar'kov. 22 pp.

196. PIRAKHUNOV, T. 1960. Influence of mineral fertilizers on the agricultural-chemical properties of sierozems during the decomposition of the roots of perennial grasses. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Tashkentsk. s.-kh. in-t). Tashkent. 18 pp.

197. Increasing the fertility of coarse soils. 1960. (Mathematical scientific methodology conference from July 25-31, 1959, at Minsk). Moscow, Izd. M-va s. kh. SSSR. 472 pp.

198. RUSKOV, V. YE. 1960. Problems of the application of fertilizers to corn on sandy loam sod-podzolic soils of the Moscow Oblast'. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Vsesoyuz. n.-i. in-t udobr. i agropochvov). Moscow. 16 pp.

199. SEREDA, N. I. 1960. Increasing fertility of peat-bog soils in the Ukrainian SSR. Kiev, Gossel'khozizdat USSR. 88 pp. with illustr. In the Ukrainian language.

200. SULEYMANOV, S. I. 1960. Certain results of the use of the T. S. Mal'tsev system under conditions of southern Murgana. Izvestiya (Akad. s.-kh. nauk AzSSR). No. 3:73-85. Summary in the Azerbaydzhan language.

201. TYULIN, A. F. 1960. Interrelationship between the rhythms of the formation of the shoot of higher plants and the rhythms of the content of nutrients available to roots in the soil. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 47:5-14. Bibliog. p. 14.

202. KHAN' TSZIN'-FYN. 1960. Influence of mineral fertilizers on the yield and quality of corn in the forest steppe of the

Ukrainian SSR. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Ukr. Akad. s.-kh. nauk). Diev. 18 pp.

203. BALKSS, R. 1960. Uber die Kaliversorgung von Lössböden. Land. Wbl. Westf. u. Lippe, N. 4, p. 1636.

204. BEDRI, A. A. and others. 1960. Assimilation of bicarbonate by roots of different plant species. Soil Sci. 89, N 5, 257-63.

205. BERGMANN, W. 1959. Ein Vergleich zwischen Einzel-und Volldüngeranwendung Dtsch. Landwirtsch. Ht. 10 s. 496-500.

206. BERGMANN, W. 1959. Vergleichende Düngungsversuche mit Einzel-und Voldüngern. Dtsch. Landwirtsch. Ht. 11, s. 530-33.

207. BÖNIG, G., H. HEIHENER. 1960. Ertragssteigerung in Cefassversuchen durch Saatgutbehandlung mit Mikronährstofflösungen. Landwirtsch. Forsch. 13, N 1, s. 59-61.

208. BROYER, T. C., P. R. STOUT. 1959. The macronutrient elements. A review. Annual Rev. Plant Physiol. 10 p. 277-300.

209. DIERENDONEK, F. J. F., van. 1959. The manuring of coffee, cocoa, tea and tobacco. Geneva, Centre d'Etude de L-Azote. p. 205.

210. Chemical changes in irrigated soil during 28 years of differential fertilization. Berkeley, Calif. 1959, p. 381-240 Hilgardia. Vol. 28 N 15) Bibl. p. 419-30.

211. DELOYE, M., H. REBOUR. 1958. La conservation de la fertilité des soils. 3 éd. Paris. 167 p. Bibl. p. 162-64.

212. FRIMMEL, G. 1959. Über versuche mit jodhaltigen Dungemitteln. Festschr. sechsigjähr. Best. landw.-chem. Bundes Vers Anst. Linz. s. 174-80.

213. GOSE, J. A. 1960. Ammonium bicarbonate in plant nutrition. Soil Sci. 89, No. 5, p. 296-302. Bibl. p. 301-302.

214. GROSS, A. ENGRAIS. 1960. Guide pratique de la fertilisation. 2ed Paris, 408 p.

215. Hundert Jahre erfolgreiche Düngewirtschaft. Generalberichete des 3 Weltkongresse für Düngungsfragen mit allen Diskussionsbeitragen. Frankfurt a M, 1958, s. 268.

216. LEIN, H. 1960. The effect of phosphate and nitrogen fertilizing on yield and chemical composition of some grass species, white clover in pastures. Forskn. Fors, Pandbr. 11, p. 203-53. Ref. Soils and Fertiliz. No. 4, 1866.

217. MATTHEWS, B. C., C. G. SHERRELL. 1960. Effect of drying on exchangeable potassium of Ontario soils and the relation of exchangeable potassium to crop yield. Canad. J. Soil Sci. No. 1, p. 35-41.

218. MEKEL, C. M., W. A. WILLIAMS. 1960. A lysimeter study of sulfur fertilization of an annual-rang soil. J. Range Manag. 13, No. 3, p. 113-17. Bibliog. 17 ref.

219. MILLER, G. W. 1960. Carbon dioxide-bicarbonate absorbtion, accumulation, effects on various metabolic reactions and possible relations and to lime-induced chlorosis. Soil Sci. 89, No. 5, p. 241-45.

220. MUKERJY, B. K., A. SINGH. 1959. Soil management problems of canal irrigated belts of India. J. Soil and Water Conservat. India. 7, No. 4-5, p. 84-90.

221. PAAUW, F. van der. 1960. Die optimale Versorgung von Boden und Pflanze mit Phosphor. Landwirtsch. Forsch Sonderht, 14, 7, s. 55-60.

222. Report of phosphorus in fertilizers. I. Photometric determination of water-soluble and citrate-insoluble phosphorus. 2. Direct determination of available phosphorus by the volumetric method. 3. Continuous versus intermittent agitation in the citrate digestion for insoluble phosphorus. J. Assoc. Offic. Agric. Chemists, 1959. 42, No. 3, p. 503-18. Bibl. p. 507-518.

223. SAUERLANDT, W. 1960. Phosphor im Stalldünger. Landwirtsch. Forsch. Sonderht. 14. 7, s. 38-43.

224. SCHACHTSCHABEL, P. 1960. Umwandlung der Düngerphosphate im Boden und Erfügbarkeit des Bodenphosphors. Landwirtsch. Forsch. Sonderht 14. 7, s 30-370.

225. SCHEFFER, F., F. LUDWIEG. 1960. Bestimmung radioaktiver Spaltprodukte von Atombomben in Pflanzen: Zirko-95 Landwirtsch. Forsch. Bd. 13, Ht. I. S. 52-58.

226. SCHEFFER, F., B. ULRICH. 1960. Lehrbuch der Agrikulturchemie, 3 Teil. Humus und Humusdüngung. Bd. I. Morphologie, Biologie, Chemie und Dynamik des Humus, Stuttgardt. 266. s.

227. SCHMITT, L. 1960. Über die Ausnutzung und Nachwirkung der mineralischen Düngungsphosphosäure. Landwirtsch. Forsch. Sonderht 14, 7, s. 49-54.

228. SCHÖNHERR, W. 1960. Die Wirkung mehrjähriger Abwasserberegnung in Verbindung mit einer zusätzlichen organischen und mineralischen. Düngung auf Pflanzenbestand und Leistung einer Wiese (Arrhenastheretum) Albrecht — Thaer — Arch. 4, s. 44-74. ref. Soil and Fertiliz. No. 4, 1868.

229. STEPHENS, D. 1960. Fertilizer experiments with phosphorus, nitrogen and sulphur in Ghana. Axper. Agric. 28, N 110, p. 151-64.

230. TEPE, W., E. LEIDENFROST. 1960. Ein Vergleich zwischen pflanzenphysiologische

kinetischen und statischen Bodenuntersuchungswerten 2. Mitteilung. Landwirtsch. Forsch., 13, Ht. 2, S. 96-113.

231. TILO, S. N. and others. 1959. Effect of four years of cropping to corn with and without fertilization on the nutrient status of Lipa clay loam. Philipp. Agric. 43, p. 341-47.

232. TROCMÉ, S., J. DELAS. 1960. Action des engrais phosphatés et bilan du phosphorus au cours d une expérience culturale de 13 années. Compt. rend Acad. agric. France, No. 2 p. 81-89.

233. ULRICH, B. 1959. Theoretische Betrachtungen zur Frage der Phosphat Wirkung. Landwirtsch. Forsch. 12, Ht. I, s. 30-36.

234. WISTINGHAUSEN, C. van. 1960. Uber die Aufgaben der Bearbeitung schwerer Böden. Mitt. Dtsch. Landwirtschafts-Ges. 75, H. 33, s. 1017-18.

235. YOUNG, R. A. and others. 1960. Influence of long-time fertility management practice on chemical and physical properties of a Fargo clay. Soil Sci. Sco. America Proc. No. 2, p. 124-28.

AIBS Russian Monograph Translations

The AIBS is in the process of expanding its Russian Translations Program extensively. Funds to subsidize translation and publication of important Russian literature in biology have been obtained from the National Science Foundation, as part of a larger program to encourage the exchange of scientific information between the two countries. The following monographs have been published:

Origins of Angiospermous Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
68 pp. [13 illustrations] 8½ x 10¾. $3.00, individuals and industrial libraries (U.S. & Canada); $2.00, AIBS members and all other libraries; $.50 additional, foreign.

Essays on the Evolutionary Morphology of Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
144 pp. [32 illustrations] 8½ x 10¾. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Problems in the Classification of Antagonists of Actinomycetes. *By G. F. Gause*
Edited by David Gottlieb. Translated by Fritz Danga
165 pp. [18 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Arachnida. Vol. IV, No. 2. Fauna of the U.S.S.R. *By B. I. Pomerantzev*
Edited by George Anastos. Translated by Alena Elbl.
199 pp. [638 illustrations] 7 x 10. $10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Arachnoidea. Vol. VI, No. 1. Fauna of the U.S.S.R. *By A. A. Zachvatkin*
Translated and edited by A. Ratcliffe and A. M. Hughes
567 pp. [705 illustrations] 7 x 10. $10.00, individuals and industrial libraries; (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Marine Biology. Trudy Institute of Oceanology. Vol. XX. *Edited by B. N. Nikitin*
302 pp. [66 illustrations] 8½ x 10¾. $10.00, individuals and industrial libraries; (U.S. & Canada; $7.50, AIBS members and all other libraries; $1.00, additional, foreign.

Plants and Xrays. *By L. P. Breslavets*
Editor of English Edition: Arnold H. Sparrow
115 pp. [26 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Wintering of Plants. *By I. M. Vasil'yev*
Editor of English edition: Jacob Levitt.
$9.00, individuals and industrial libraries (U.S. & Canada); $8.00, AIBS members and all other libraries; $.50, additional, foreign.

Monogenetic Trematodes, Their Systematics and Phylogeny. *By Boris E. Bychowsky.*
Editor of English edition: William J. Hargis, Jr.
$10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $.50, additional, foreign.

For orders and a FREE copy of our Publications Catalog listing all AIBS Publications, write to:

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
2000 P Street, N.W. Washington 6, D. C.

AGRONOMY SEMINAR
305 DAVENPORT HALL

TRANSLATIONS OF RUSSIAN BIOLOGICAL JOURNALS

The American Institute of Biological Sciences, under a grant from the National Science Foundation, is currently translating and publishing seven Russian research journals in biology.

DOKLADY: BIOLOGICAL SCIENCES SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$20.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$15.00 per year, AIBS members and all other libraries
$2.50 additional to each price, foreign
$4.00 each, single copies

DOKLADY: BOTANICAL SCIENCES SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$7.50 per year, individuals and industrial libraries (U.S.A. & Canada
$5.75 per year, AIBS members and all other libraries
$1.50 additional to each price, foreign
$1.50 each, single copies

DOKLADY: BIOCHEMISTRY SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$15.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$10.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$4.50 each, single copies

PLANT PHYSIOLOGY • FIIZIOLOGIYA RASTENIY

6 issues per year. First issues published: 1957. Vol. 4, Nos. 1-6. Current issues published: 1961, Vol. 8, Nos. 1-6.

Subscriptions:

$15.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$11.00 per year, AIBS members and all other libraries
$2.00 additional to each price, foreign
$3.00 each, single copies

SOVIET SOIL SCIENCE • POCHVOVEDENIYE

12 issues per year. First issues published: 1958. Current issues published: Jan.-Dec., 1960.

Subscriptions:

$20.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$15.00 per year, AIBS members and all other libraries
$2.50 additional to each price, foreign
$4.00 each, single copies

MICROBIOLOGY • MIKROBIOLOGIYA

6 issues per year. First issues published: 1957, Vol. 26, Nos. 1-6. Current issues published: 1961, Vol. 30, Nos. 1-6.

Subscriptions:

$40.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$20.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$4.50 each, single copies

ENTOMOLOGICAL REVIEW
ENTOMOLOGICHESKOYE OBOZRENIYE

4 issues per year. First issues published: 1958. Current issues published: 1961, Vol. 40, Nos. 1-4.

Subscriptions:

$25.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$12.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$7.50 each, single copies

Order from:

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
2000 P Street, N.W. Washington 6, D. C.